

ACKNOWLEDGEMENT

:Namo Buddhay:

In everyone's life, the day arises when one has to shape the feelings in words. Sometimes, the words become unable to express the feelings of mind; because the feelings of heart are beyond the reach of the words. When I came to complete this manuscript, so many memories have rushed through my mind, which are full of gratitude's to those who encouraged and helped me at various stages of this research work and also throughout my life. It gives me an immense pleasure to record my feelings at this juncture.

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The Associate Dean,
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Subject: Regarding submission of final bound thesis of Ph.D.student

Respected Sir,

please find enclosed herewith a copy of Final bound Thesis of Miss Borkar Vibhawati Suresh, (Regd. No. 153), Ph.D. scholar, Department of Soil Science and Agricultural Chemistry, along with the following documents, for the futher necessary action, please.

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Thanking you.
Yours faithfully,

Department of SSAC

Head

Dr. B.S.K.K.V.Dapoli.

Encl :As above

Title of the thesis : **Movement behaviour of primary nutrients, carbamate and organophosphate based insecticides in different soil matrices**

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ABSTRACT

A pot culture experiments was conducted to study the “Movement behaviour of primary nutrients, carbamate and organophosphate based insecticides in different soil matrices” during *Kharif*, 2012 and 2013 in three replications. The experiments was conducted with three soil types dominant in region viz., Lateritic, Medium black and Coastal saline soil which included the RDF along with two sources of pesticides (Carbofuron and Phorate) with rice (*var.* Sahyandri-4). Leaching loss of nutrients and pesticides at three different stages of crop growth was determined. Another experiment repeated twice in 2012 and 2013 replicated thrice to study the movement behavior of pesticides at the different depths of soil profile at 0-30, 30-60 and 60-90 cms was determined. The leaching loss of pesticides through the column was also quantified.

The results of pot culture experiments indicated that the leaching loss of N, P and pesticides (Carbofuron and Phorate) from soil under rice crop showed that it was found to be maximum in Lateritic soil followed by Medium black and Coastal saline soil. However, leaching losses of potassium was observed maximum in Coastal saline soil. A portion of applied fertilizers gets fixed into various fractions and become unavailable to crop. Thus, fractions of N, P and K at harvest stage of rice affected due to treatments were also quantified. Ammonical-N fraction was found dominant over nitrate-N in all the three soil types because of submerged condition. In case of P-

fractions, the Lateritic soil was dominated by Fe-P however Medium black and Coastal saline soils dominated by Ca-P. As regards to K-fractions, all the three soil types were dominated by non-exchangeable K.

Application of pesticides in combination with RDF increased the availability of (N, P and K) nutrient as compared to control (RDF only) in all soil types. Phorate was found better than Carbofuron in contributing the nutrients availability as well as yield of rice. The maximum pesticide residue content in soil was observed at 30DAT in all soil types thereafter it decreased gradually upto harvest stage of rice due to degradation, leaching losses and uptake by the crop. The analysis of pesticides residue in soil under rice crop showed that it was maximum in Medium black soil followed by Lateritic soil and Coastal saline soil. Yield of rice was found to be highest in Medium black soil as compared to other soils. The pesticide residue in grain and straw of rice sample were found to be well below the residue limit fixed by WHO in all the samples.

The correlationship between soil physico-chemical properties with available N, P, K and pesticides residue in soil under rice were also worked out. A highly significant and negative relationship of sand, Infiltration Rate and organic carbon was seen with available-N (at 90DAT and AH) whereas clay and CEC were correlated significantly and positively. A highly significant and negative relationship of sand, IR and organic carbon was seen with available P whereas silt, clay, pH and CEC showed a highly significant and positive relationship. A highly significant and negative relationship of sand, organic carbon and IR was seen with available-K, whereas silt, clay, pH and CEC showed a highly significant and positive relationship. A negative relationship of clay and EC was seen with pesticides residue.

The results of the leaching column experiments indicated that, the maximum pesticides leaching loss through percolates occurred in Lateritic soil and minimum in Coastal saline soil. Among the two pesticides studied, the losses of Carbofuron were found more than Phorate due to its higher solubility in water. The pesticides residue in surface (0-30cm) soil of leaching column was found maximum upto 30th day sampling thereafter it gradually decreased due to degradation and leaching losses. The vertical downward movement of pesticides across the layers was seen maximum in Lateritic soil and least in the Coastal saline soil. Carbofuran moved faster through the layer than Phorate.

Key words: Movement behaviour, Major nutrients, Carbofuron, Phorate, Laterite, Medium black, Coastal Saline soils.

APPENDICES

DAA	Days After Application
DAT	days After Transplanting
PI	Carbofuron
PII	Phorate
CEC	Cation Exchange Capacity
EC	Electrical Conductivity
NH_4^+ -N	Ammonical nitrogen
NO_3^- -N	Nitrate nitrogen
Sal-P	Saloid-P
Ca-P	Calcium-P
Al-P	Alluminium-P
Fe-P	Iron-P
RS-P	Reductant soluble -P
OC-P	Occluded-P
Kg ha^{-1}	kilogram per hactor
$\mu\text{g kg}^{-1}$	microgram kg^{-1}
CS	Coastal saline
Lat.	Lateritic
MB	Medium black
Ava.	Available
TDM	Total Dry Matter

Exch	Exchangeable
Amm.	Ammonical
%	Percent
$\mu\text{g pot}^{-1}$	Microgram per pot
$\mu\text{g column}^{-1}$	Microgram per column
PPm	Parts per million
RDF	Recommended dose of fertilizers
IR	Infiltration rate

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MATRICES**

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By,

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CERTIFICATE

This is to certify that the thesis entitled,“ Movement Behaviour of Primary Nutrients, Carbamate and Organophosphate Based Insecticides in Different Soil Matrices” submitted to Faculty of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra State, in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Agriculture) in Soil Science and Agricultural Chemistry, embodies the results of a piece of bona-fide research carried out by Miss. VIBHAWATI SURESH BORKAR under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma or published in other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by her.

Place: Dapoli

Date :

(N. B. Gokhale)

Chairman,

Advisory Committee and Research Guide

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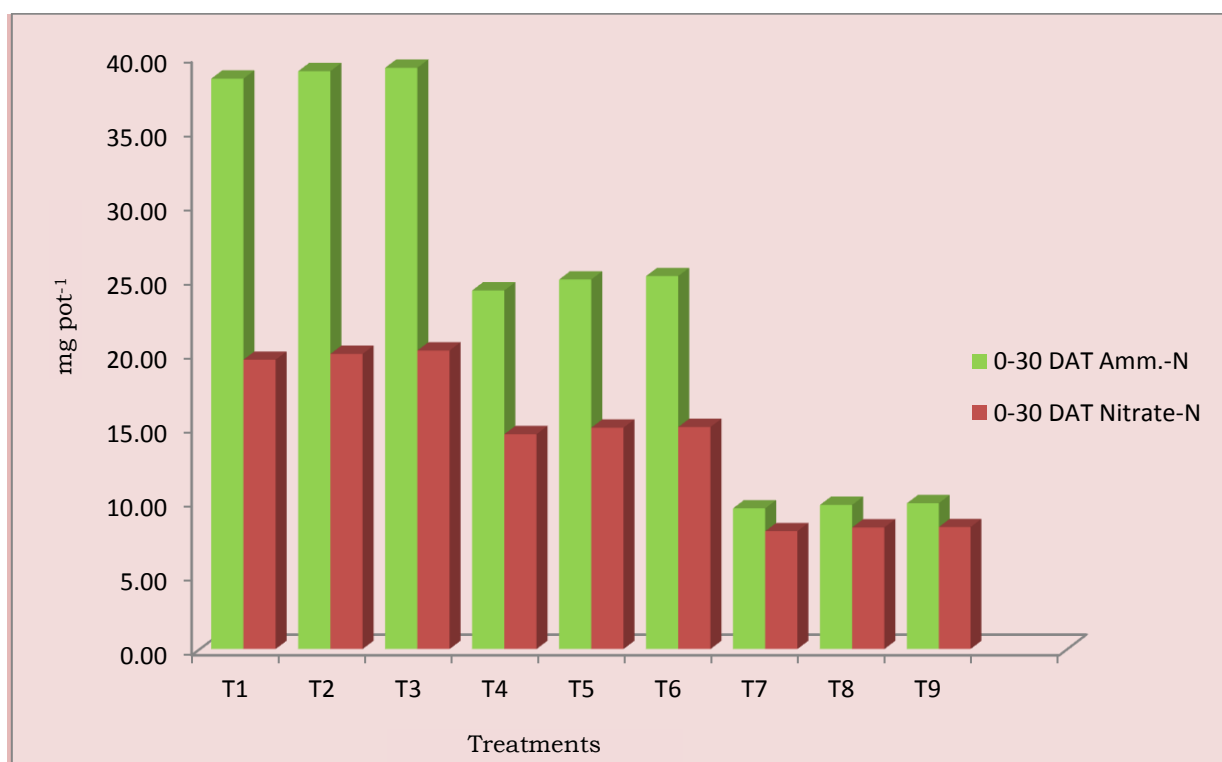


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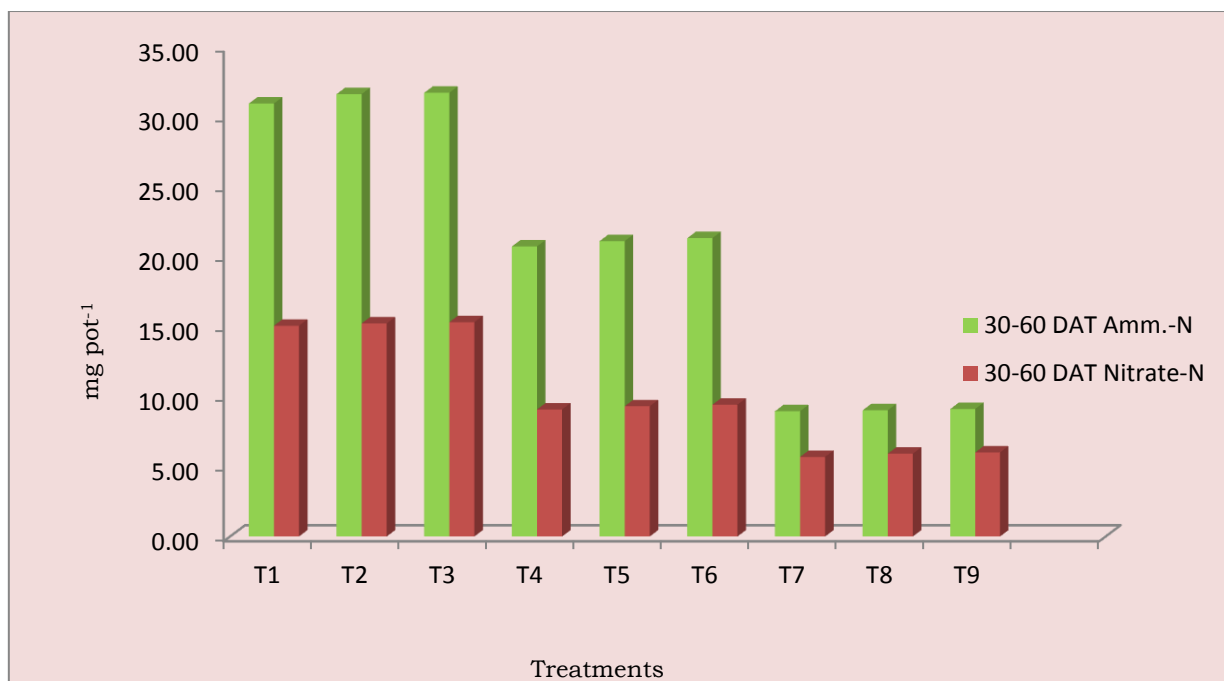


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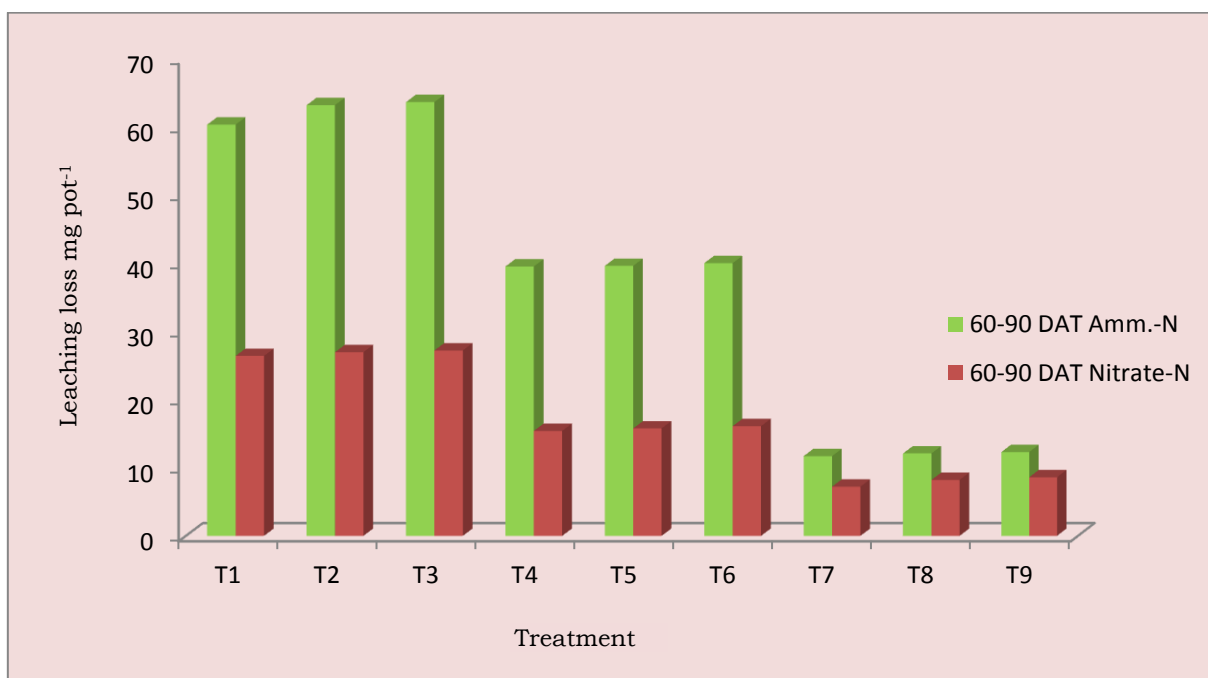


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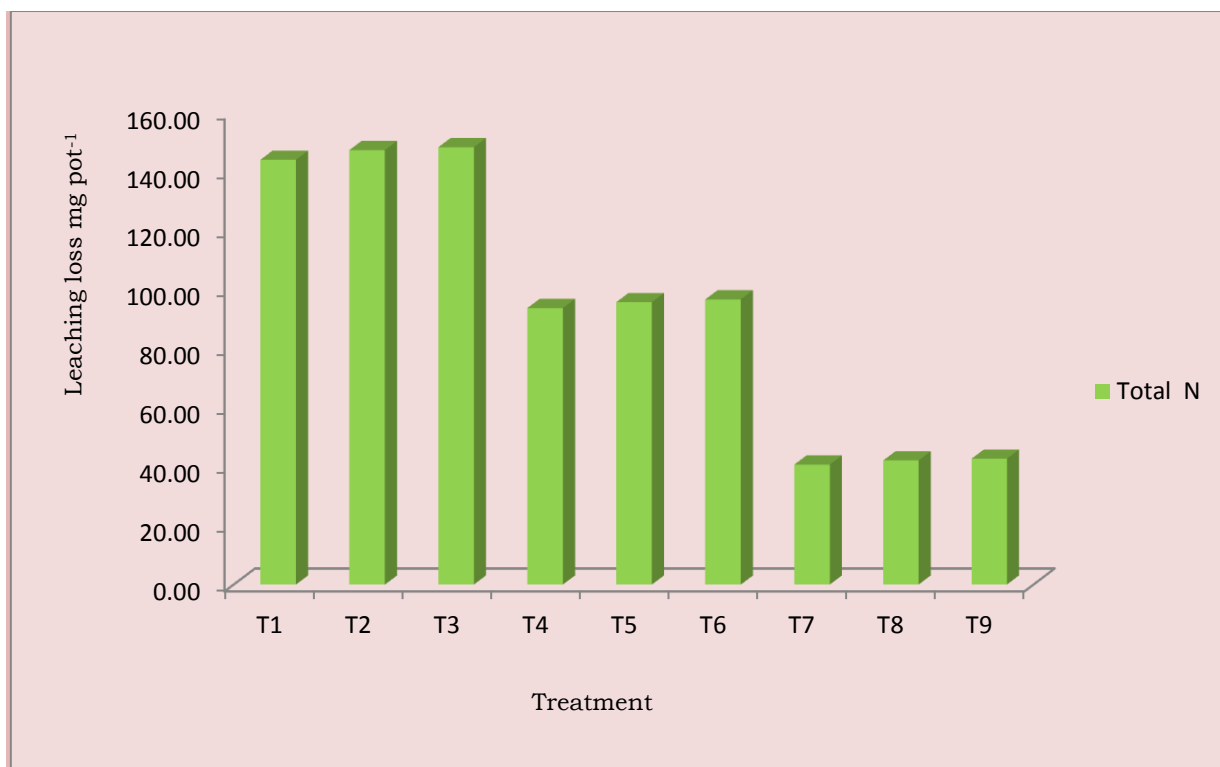


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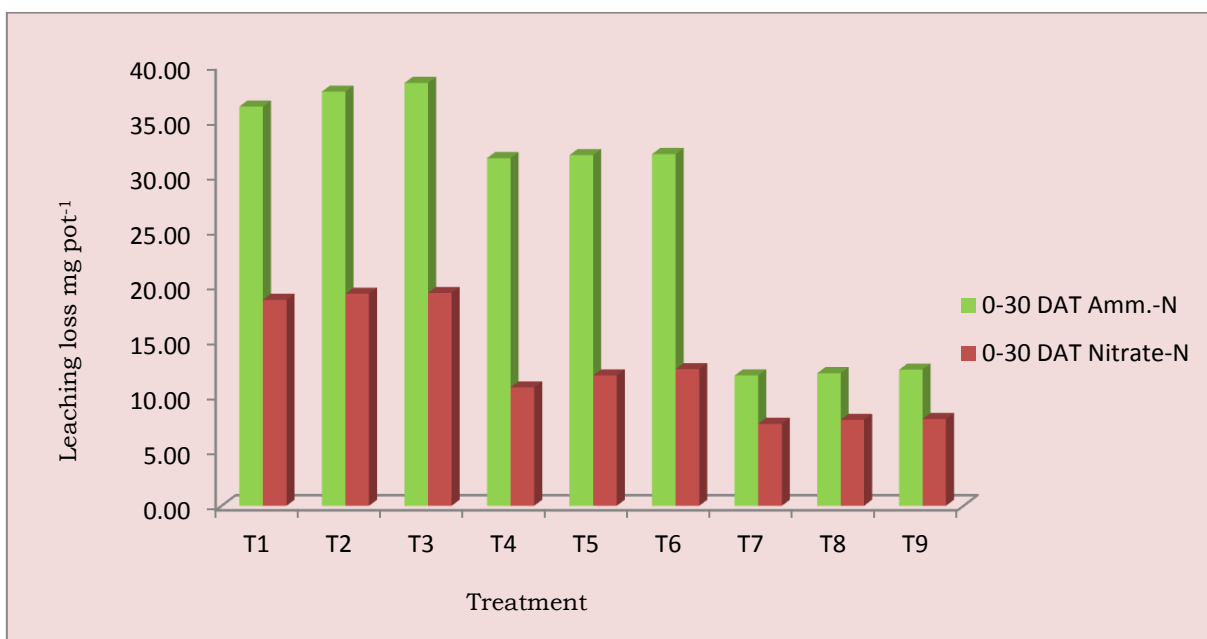


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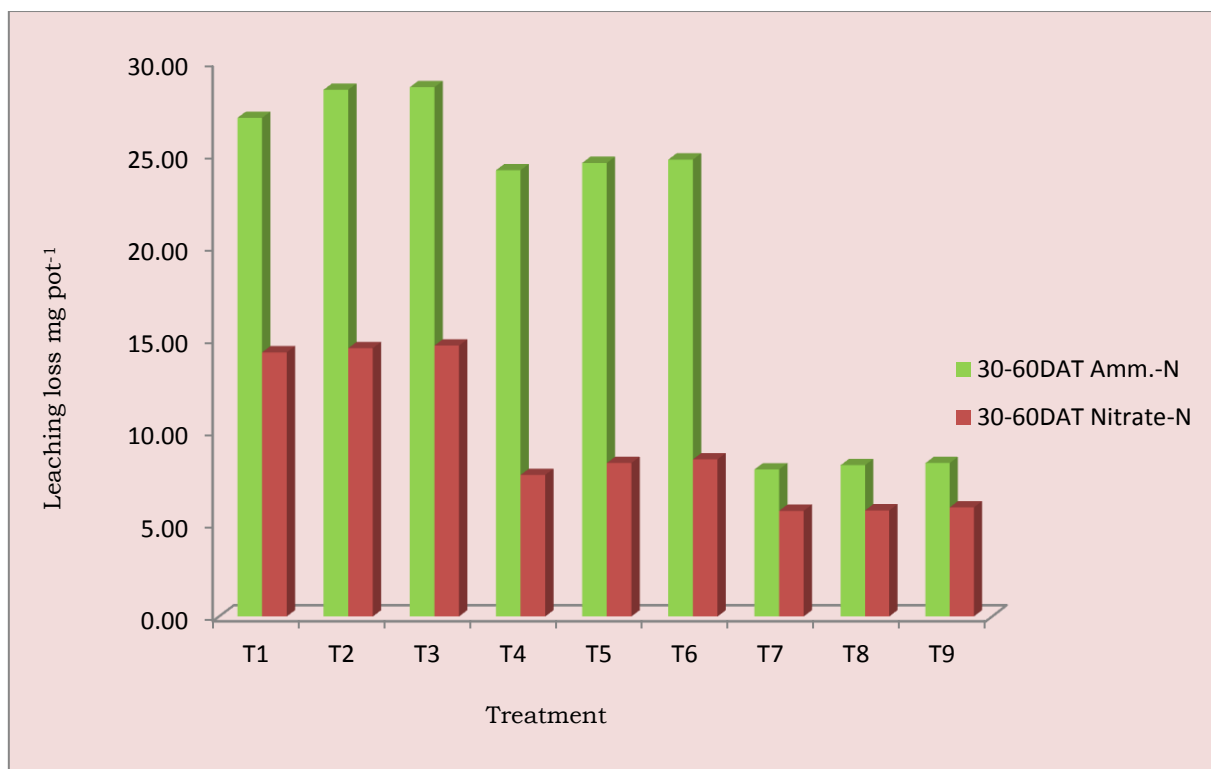


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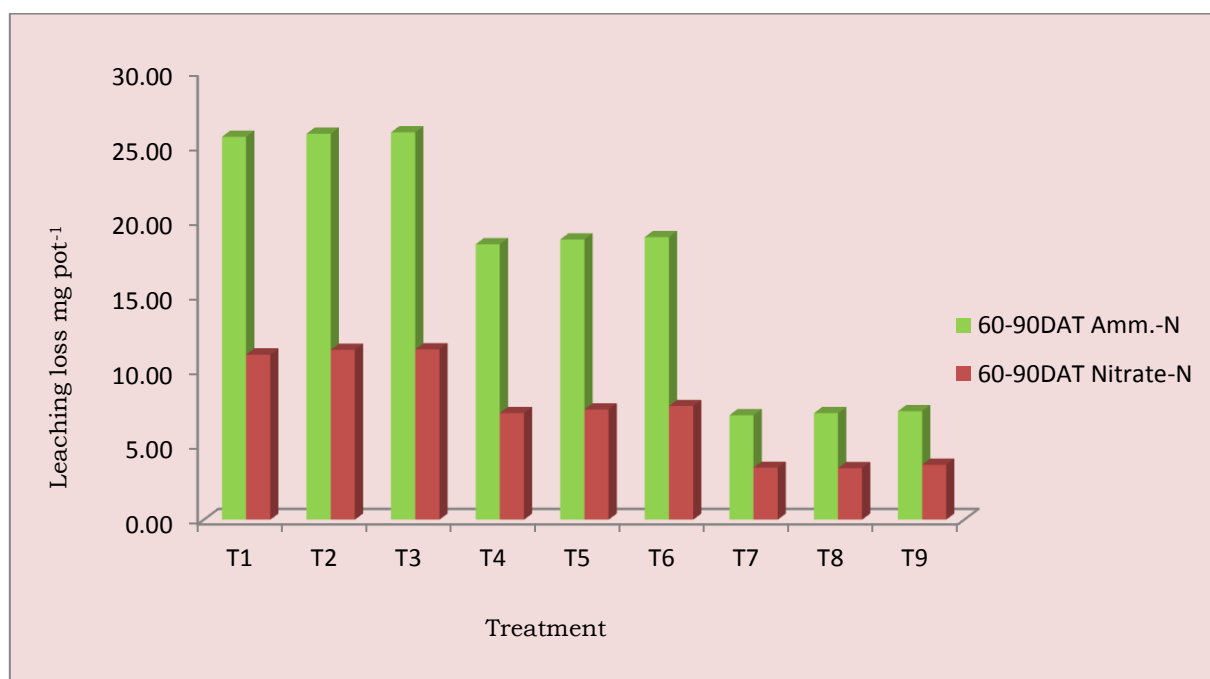


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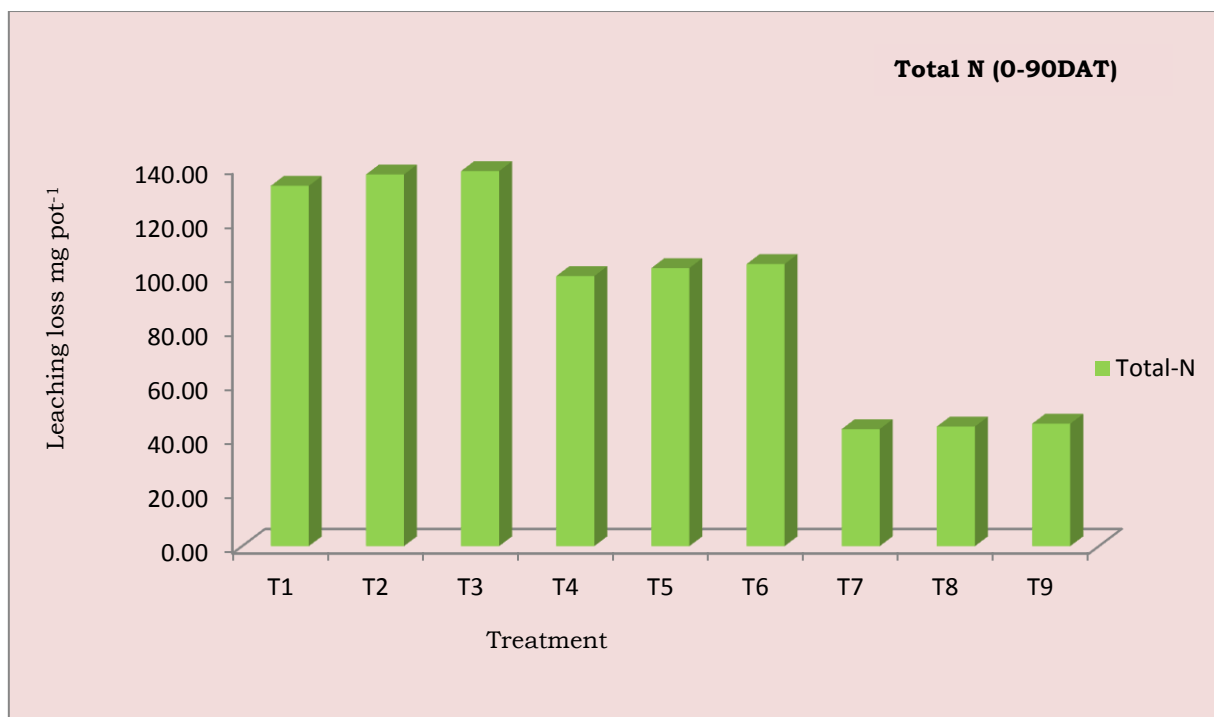


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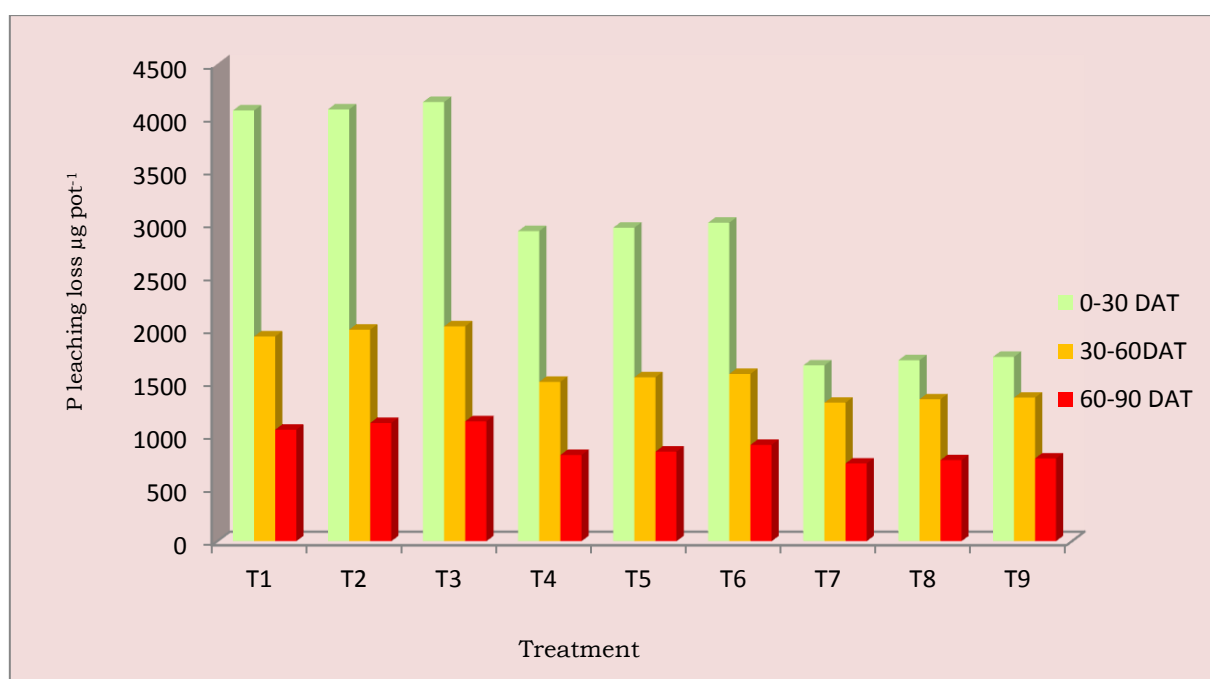


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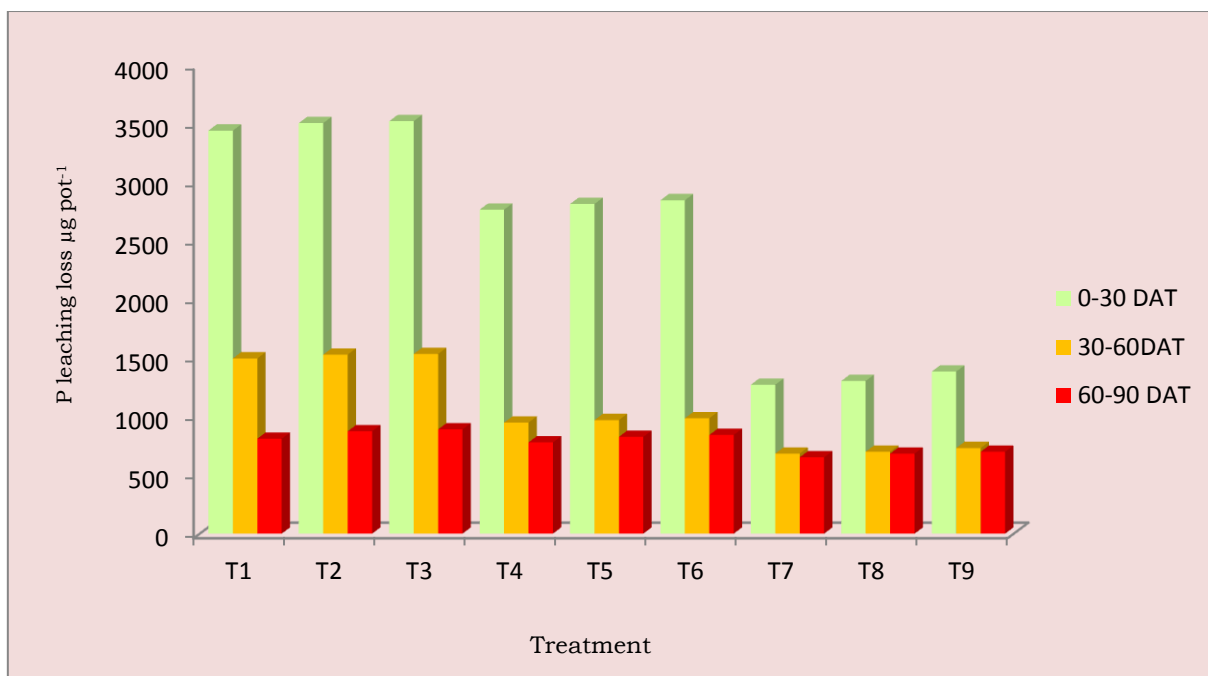


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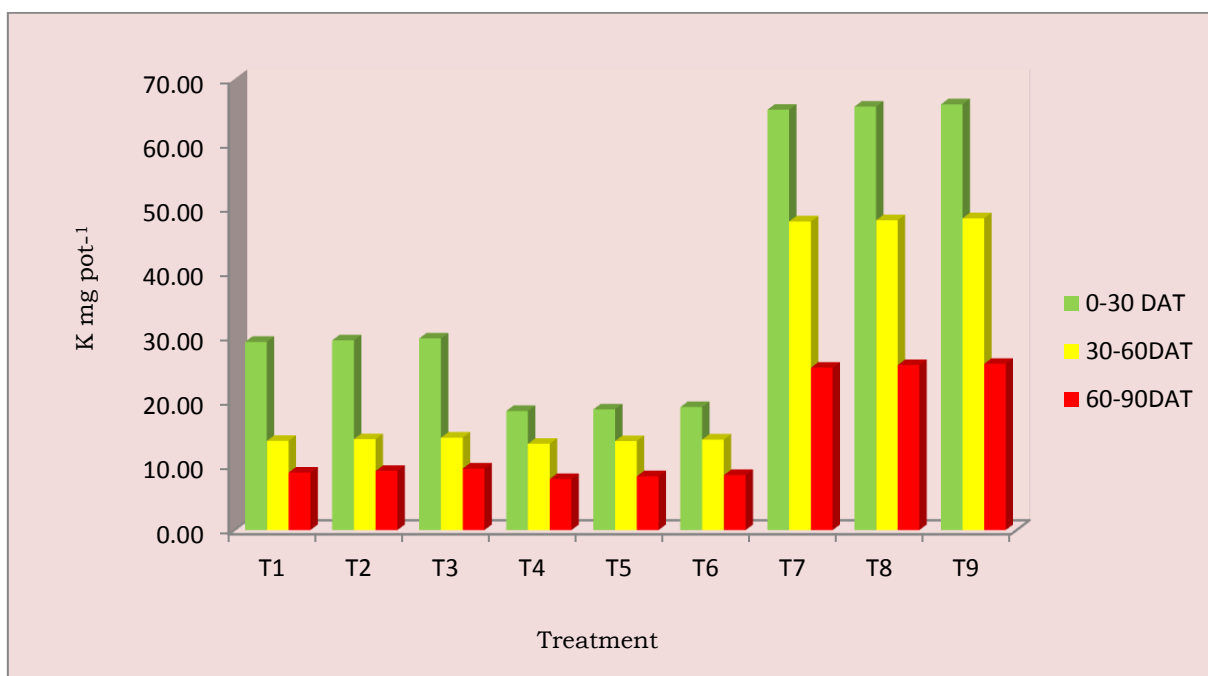


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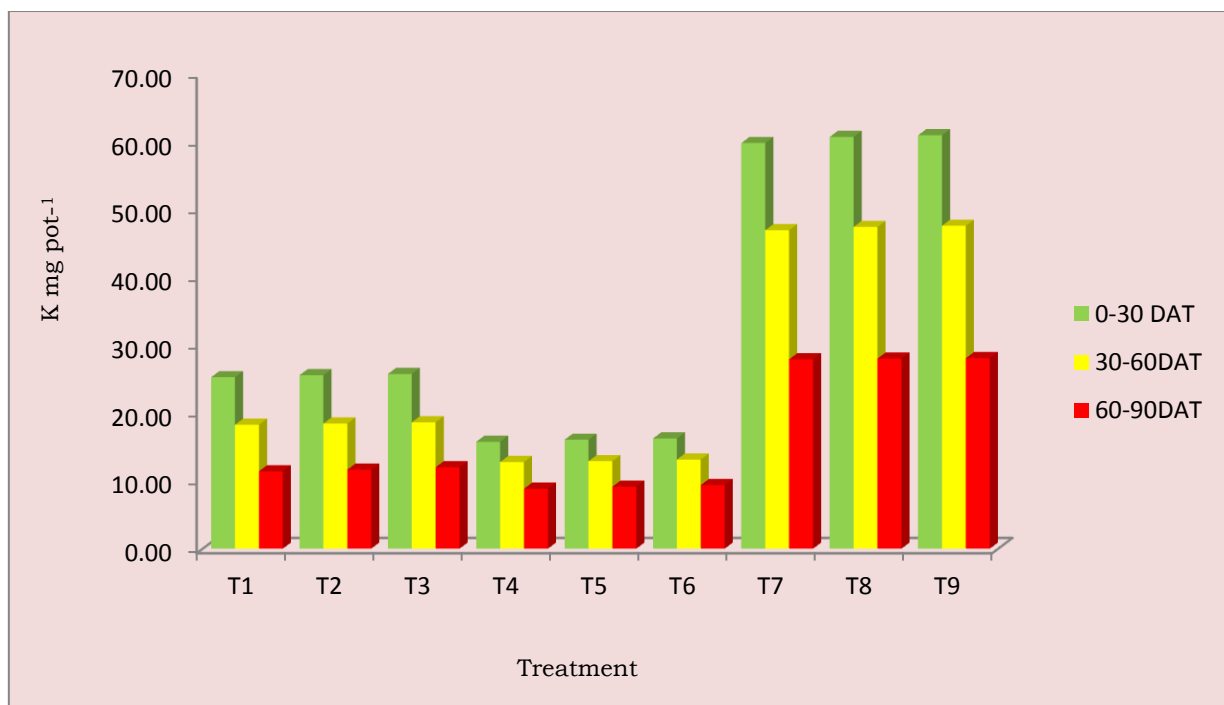
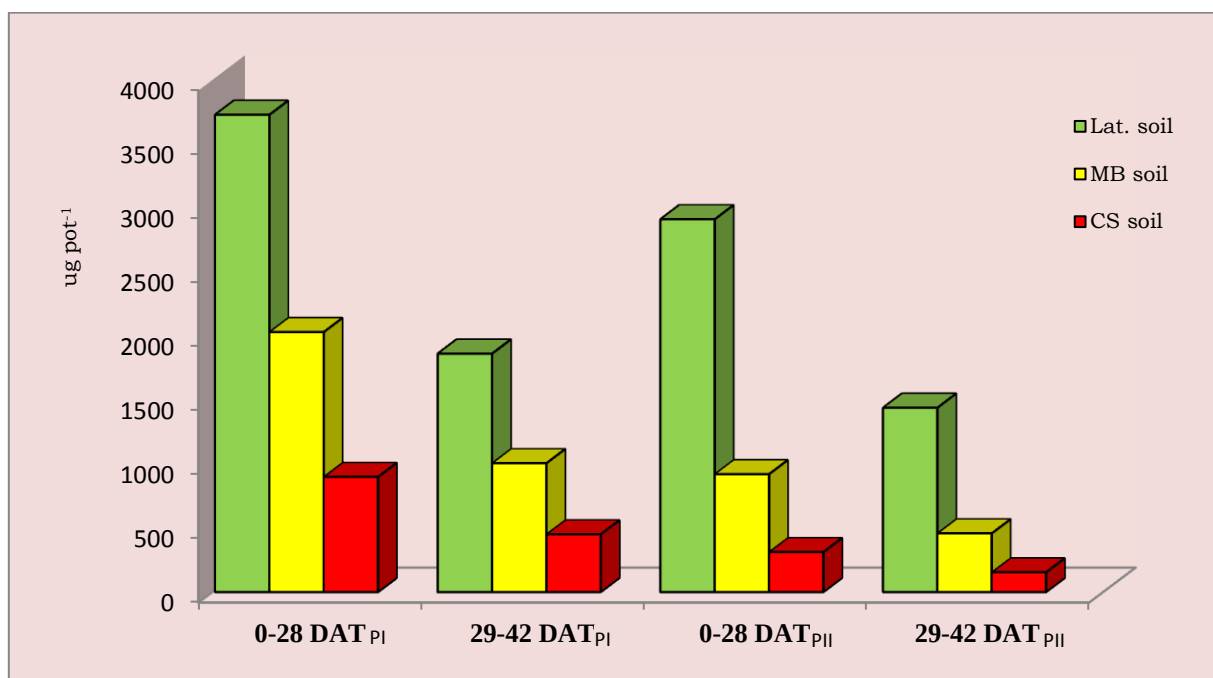
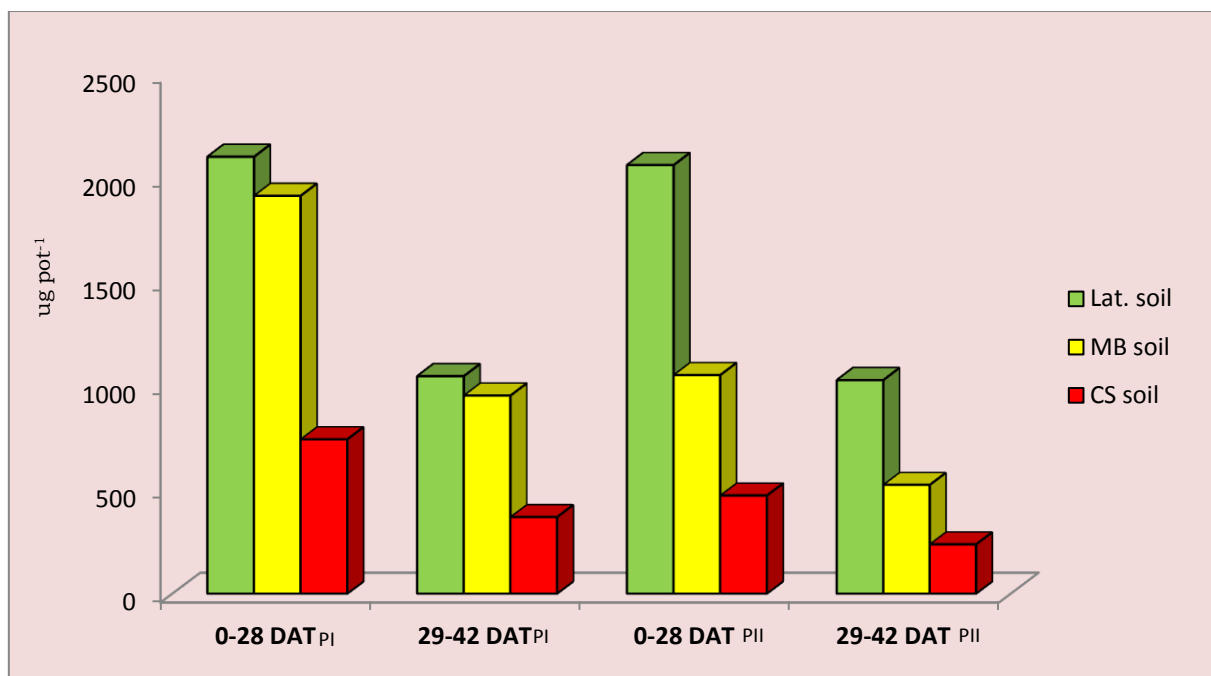


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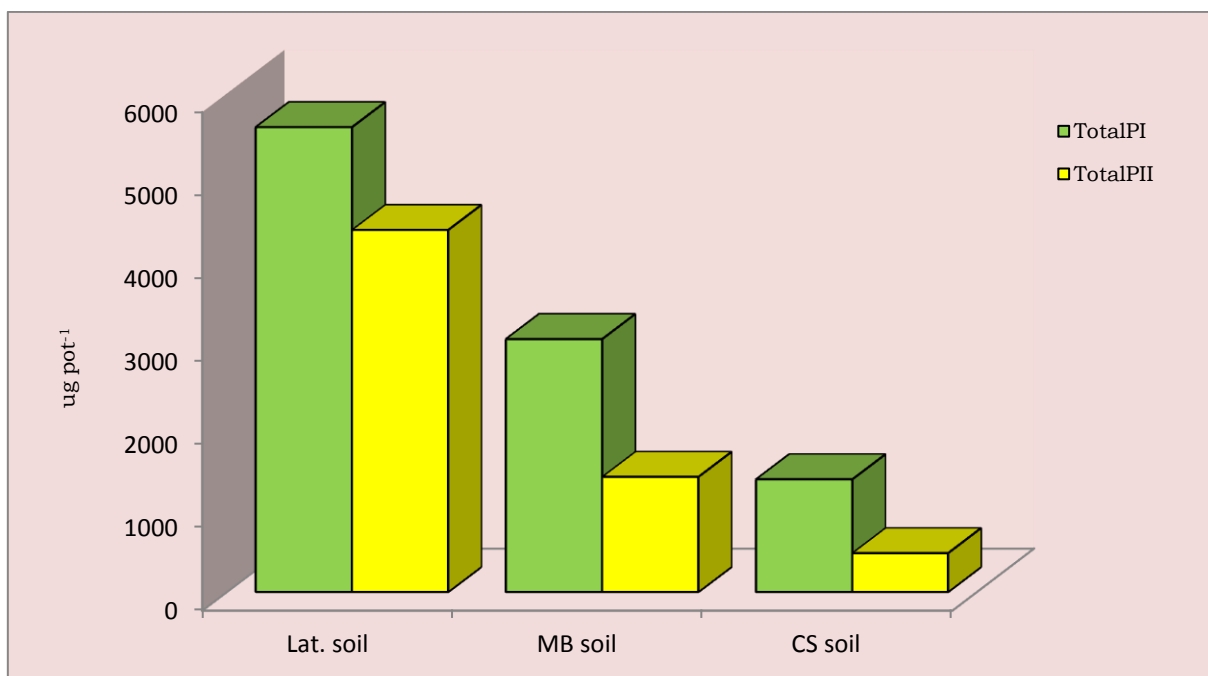
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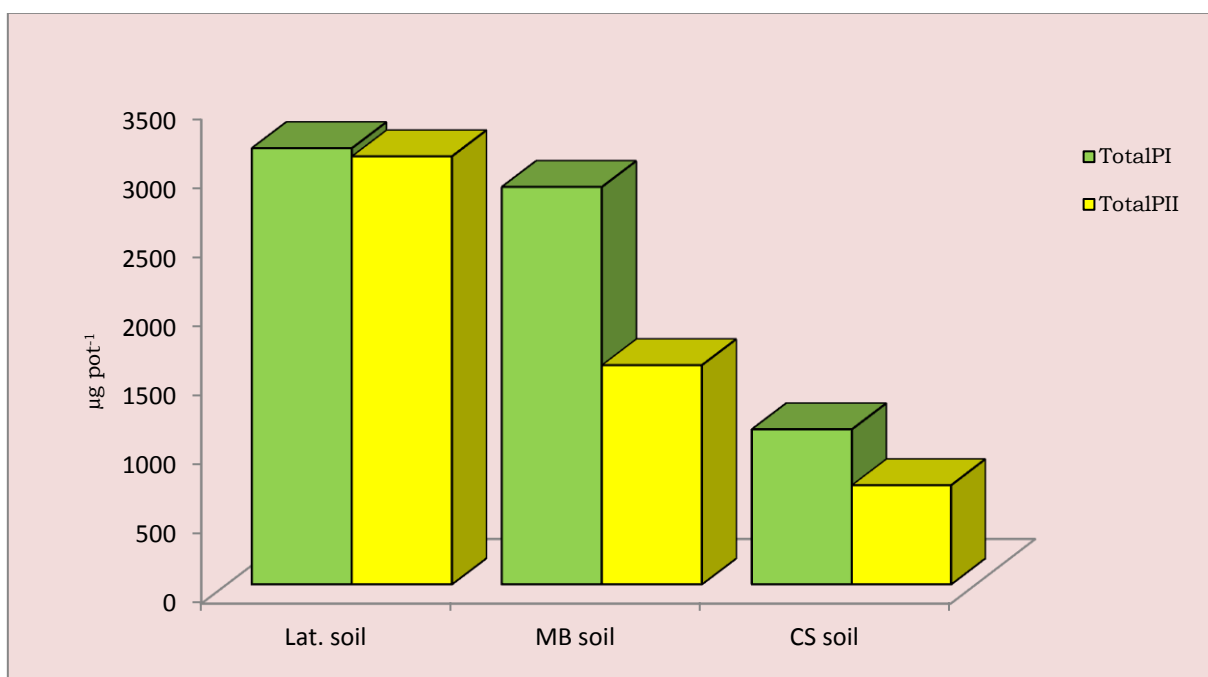
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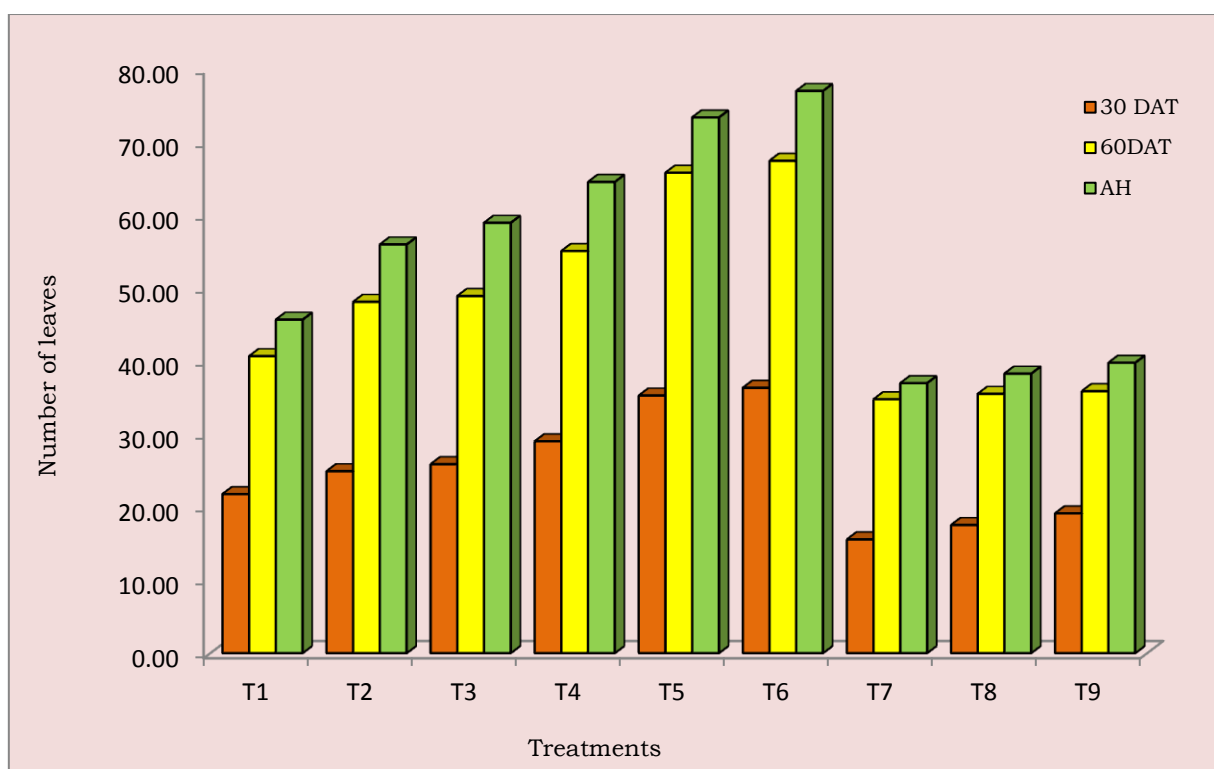


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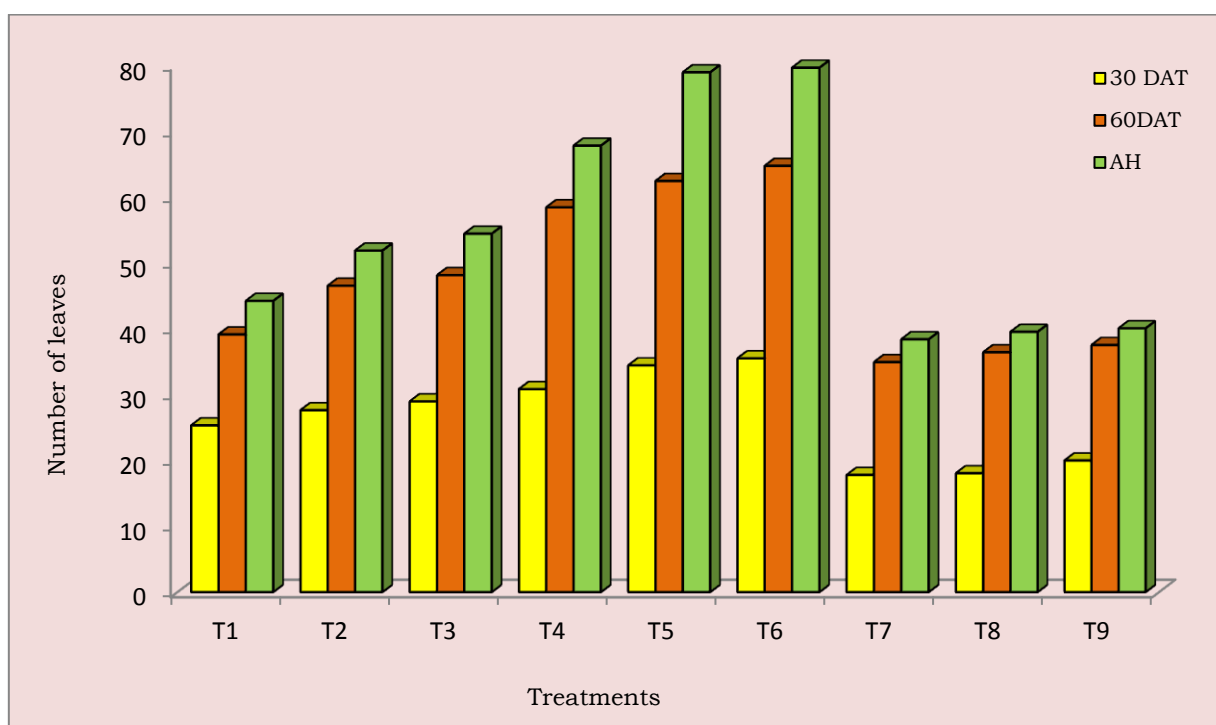


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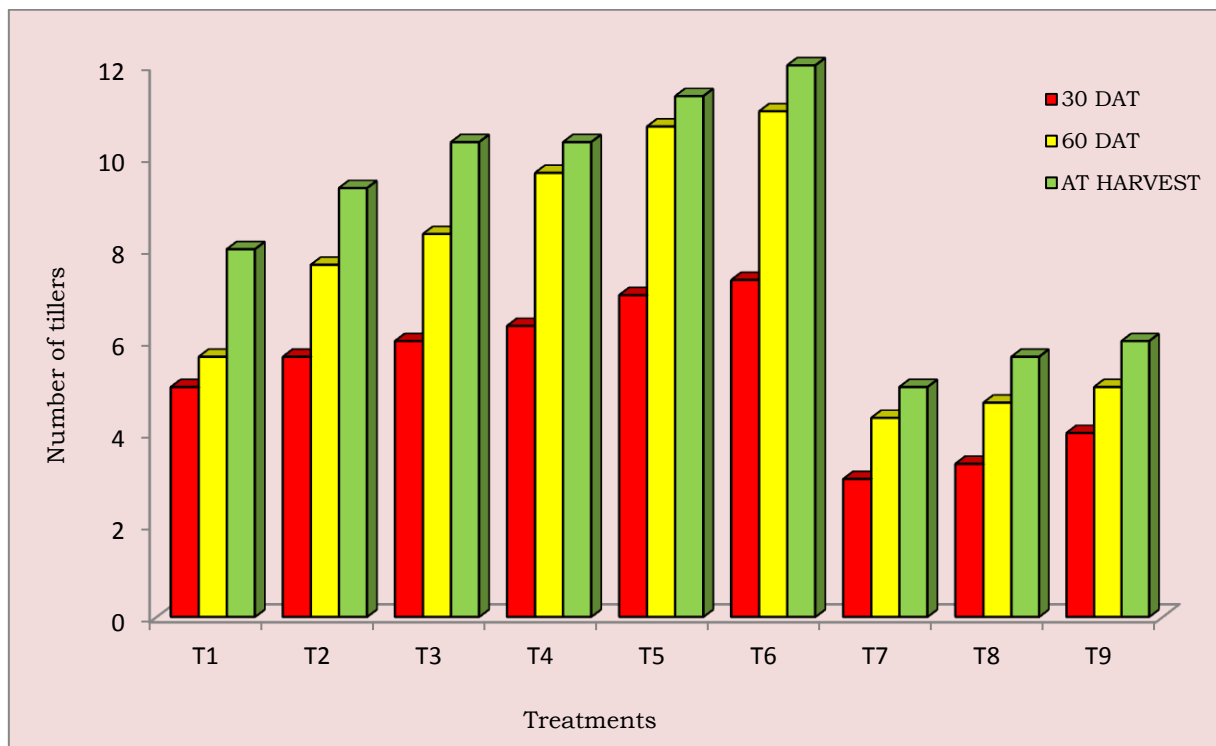


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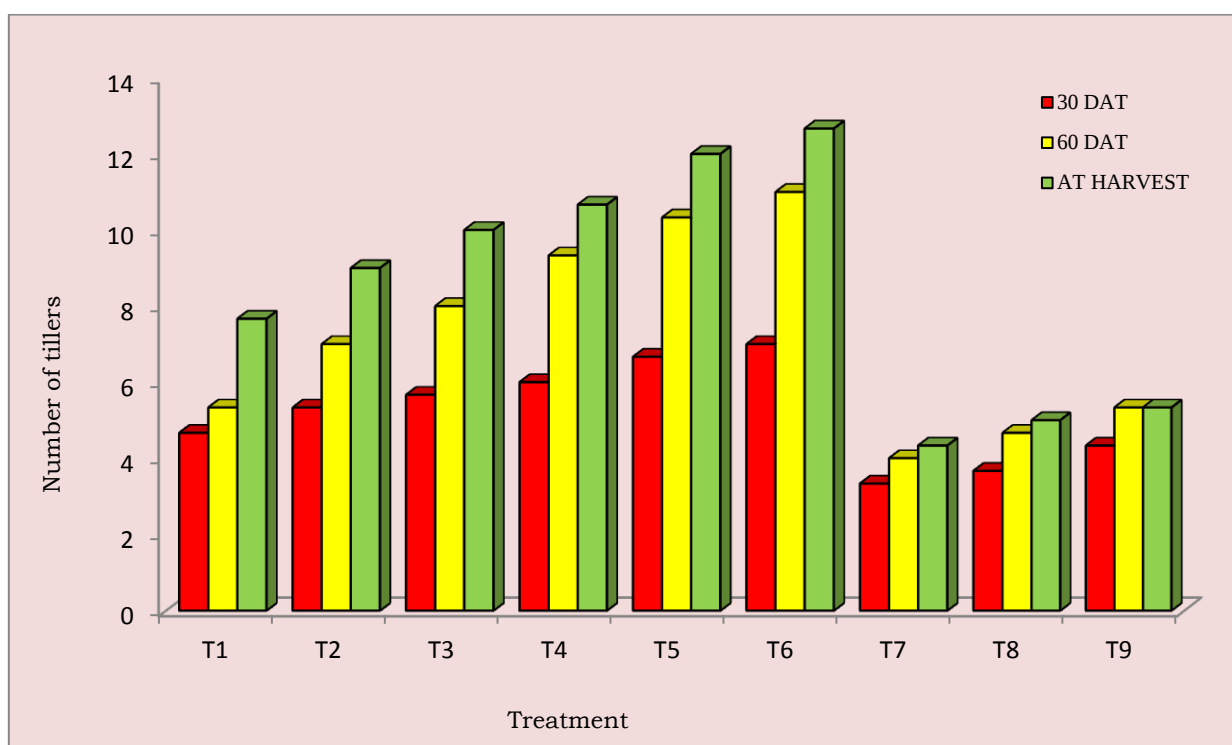
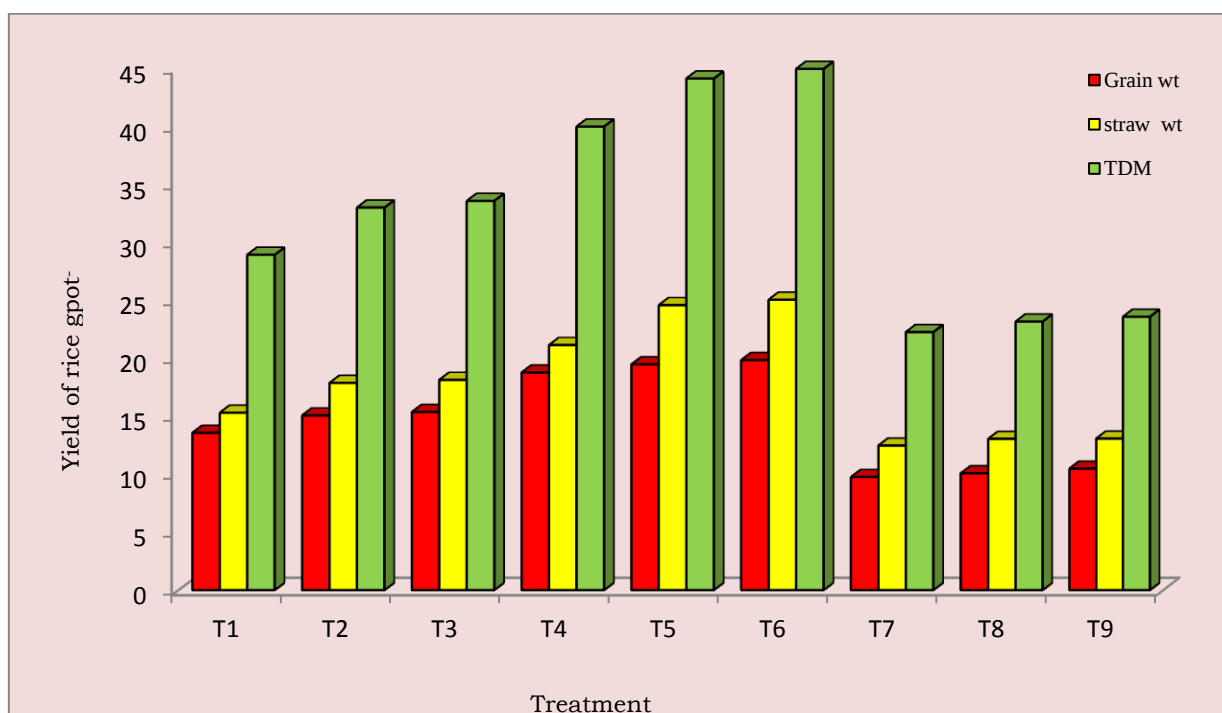
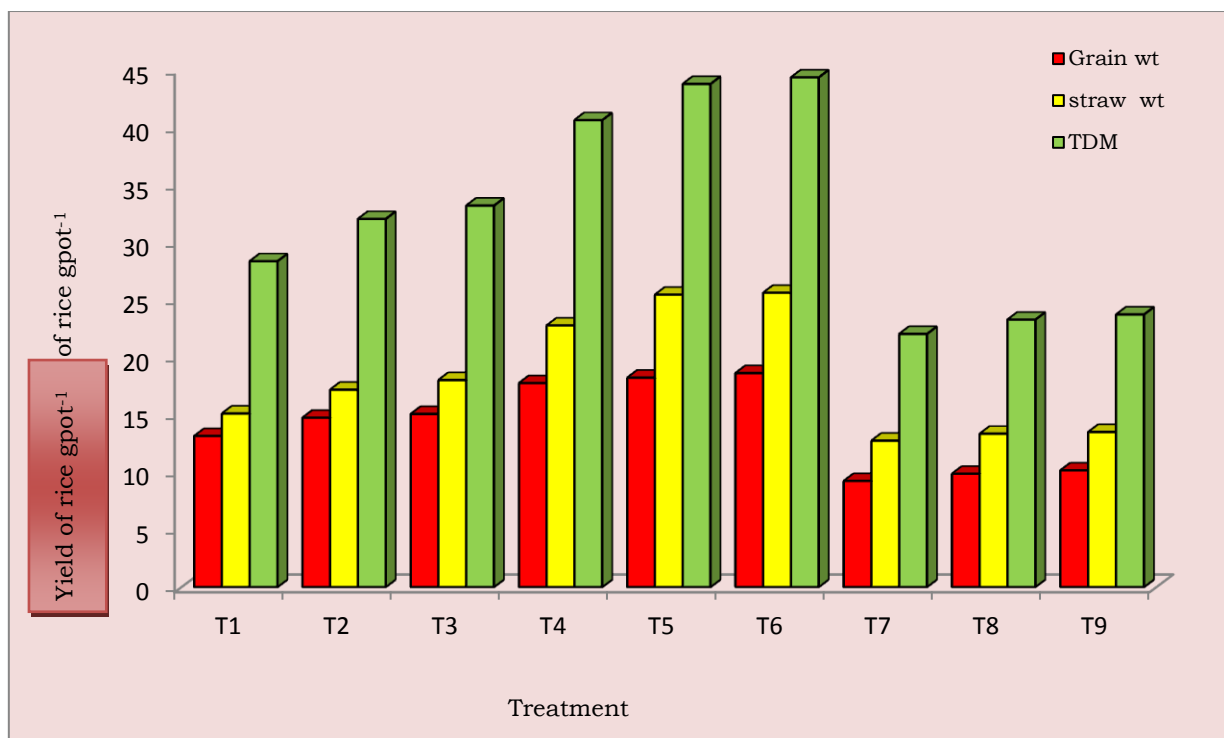


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TDM: Total Dry Matter

Fig.21: Effect of different treatments on grain and straw yield of rice (2012).



TDM: Total Dry Matter

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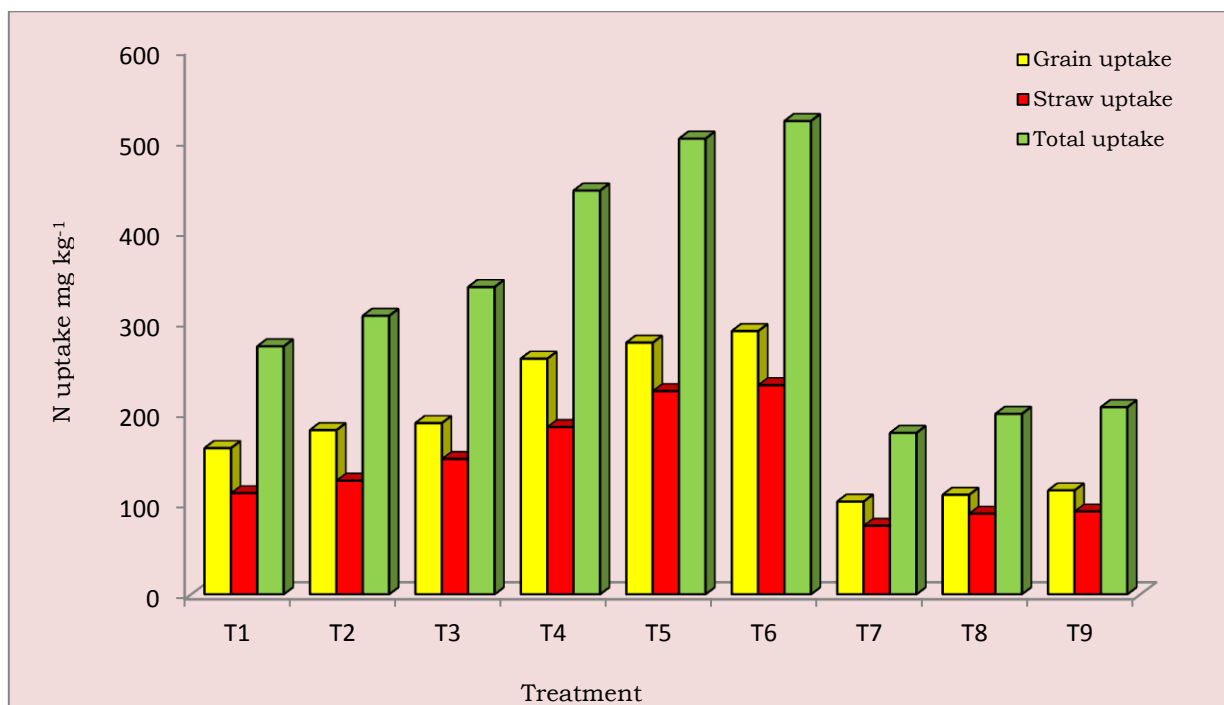


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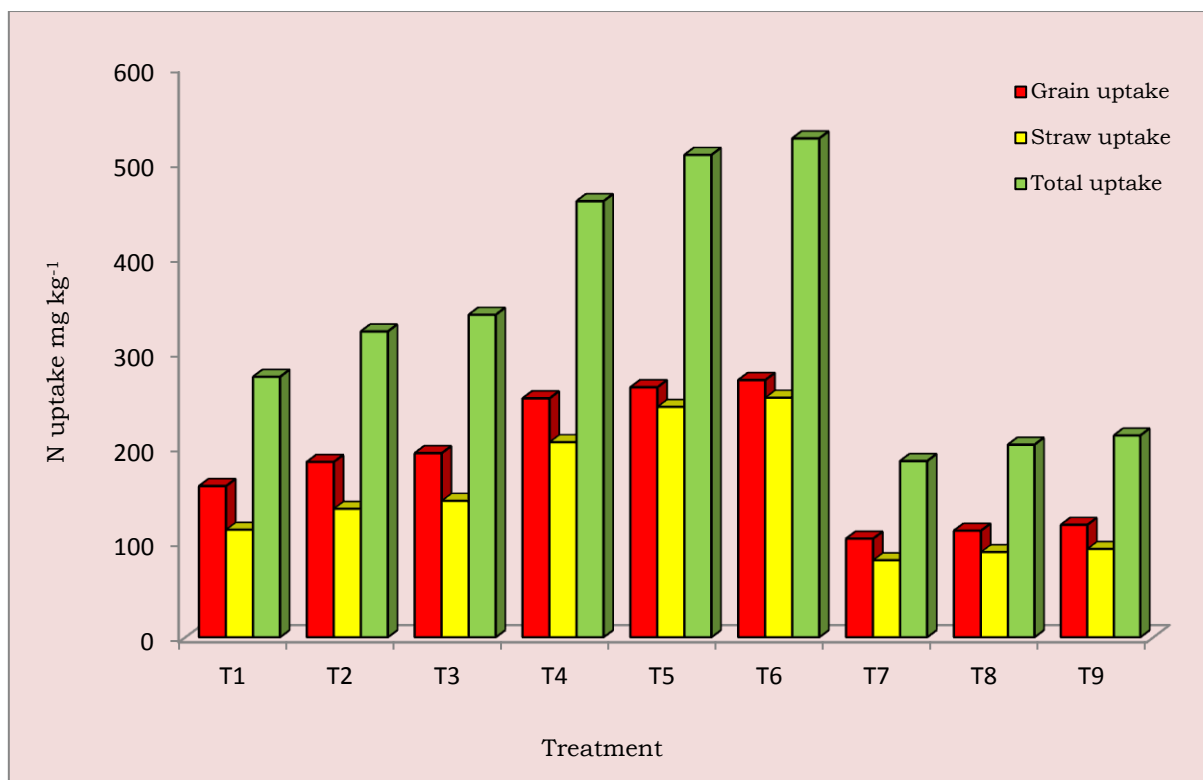


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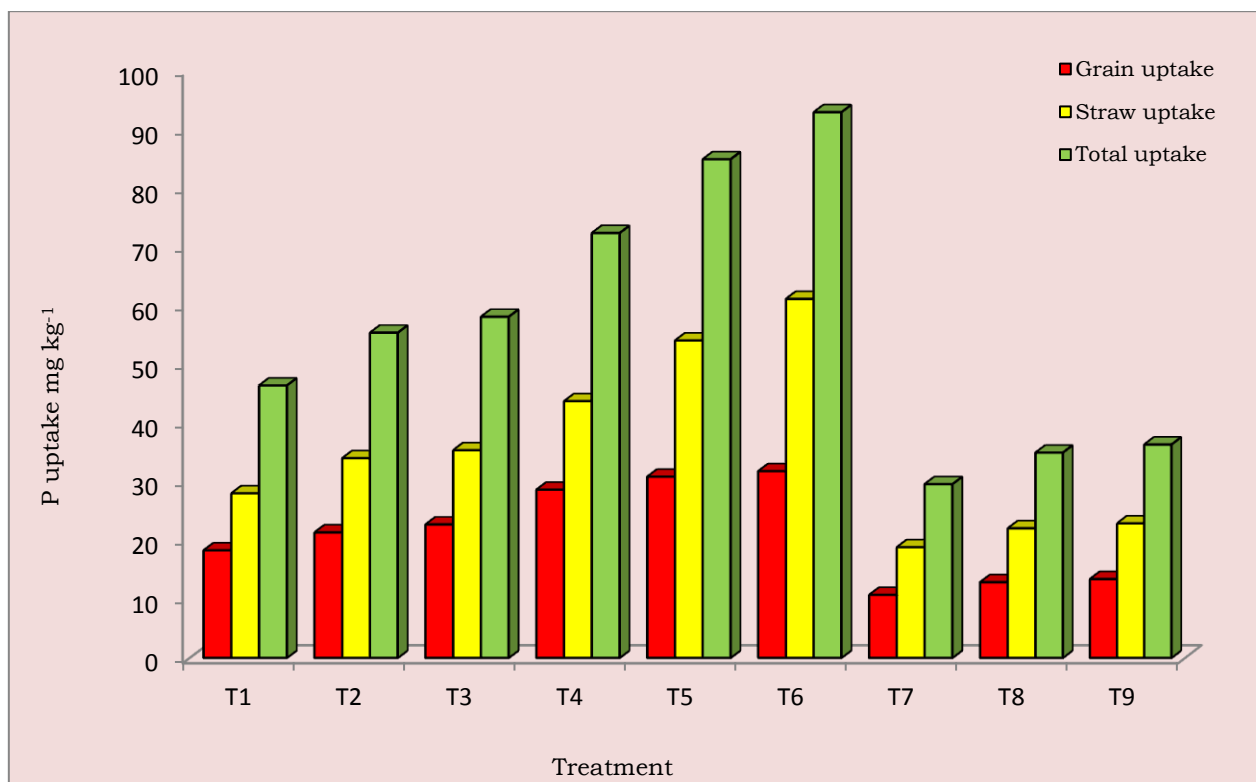


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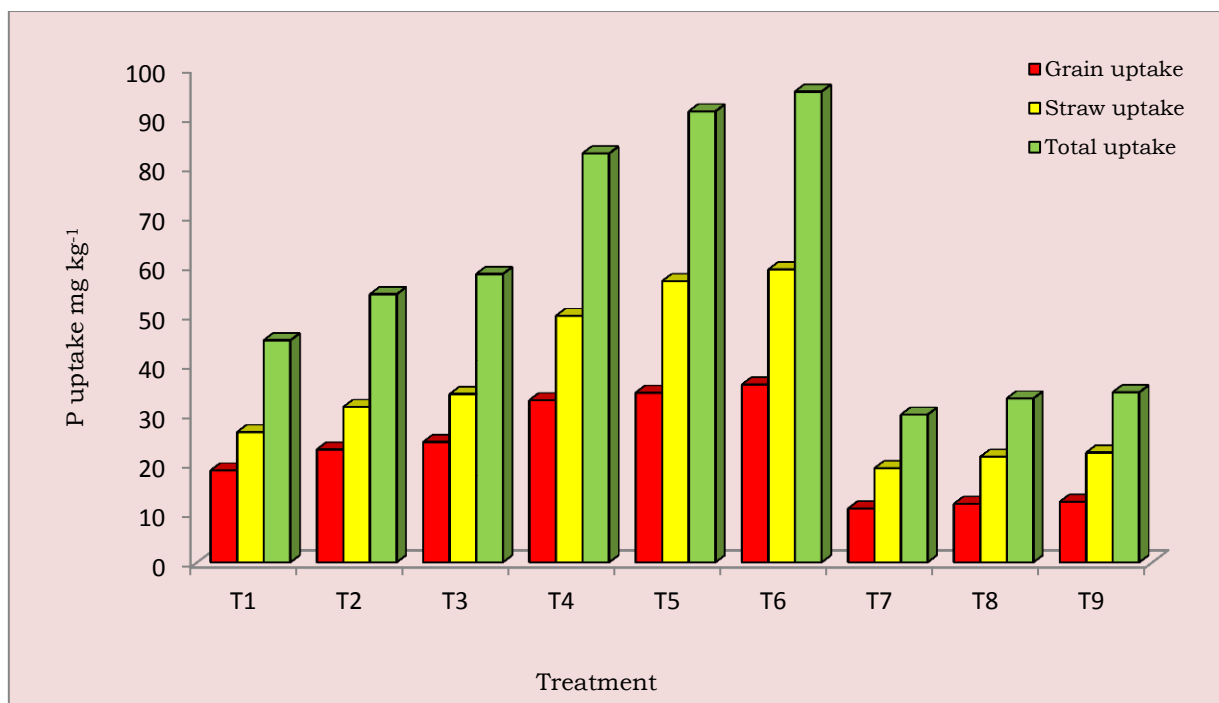


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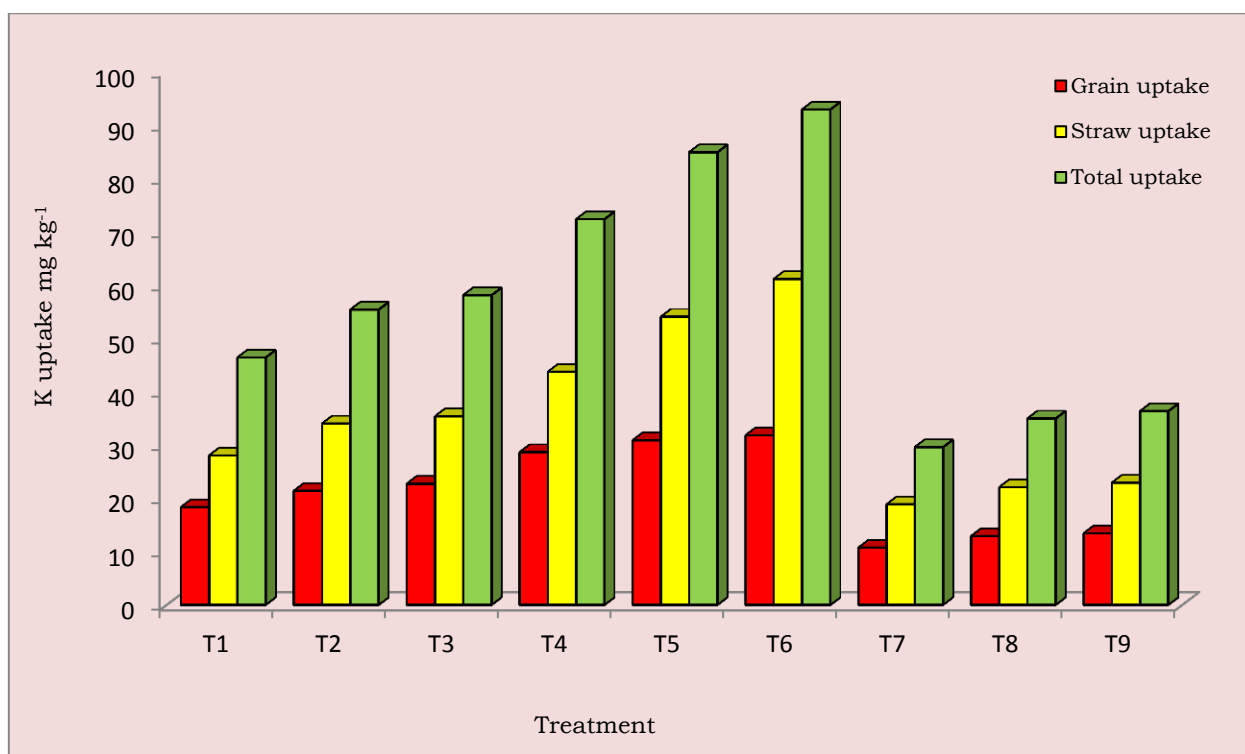


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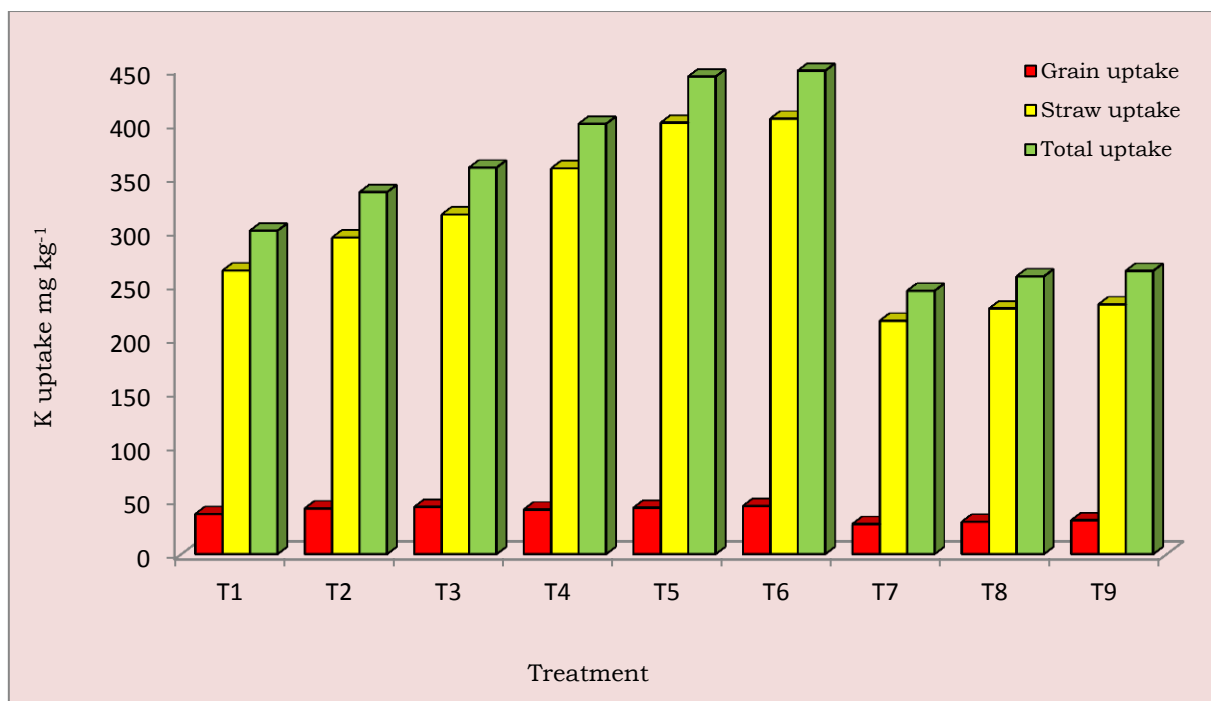
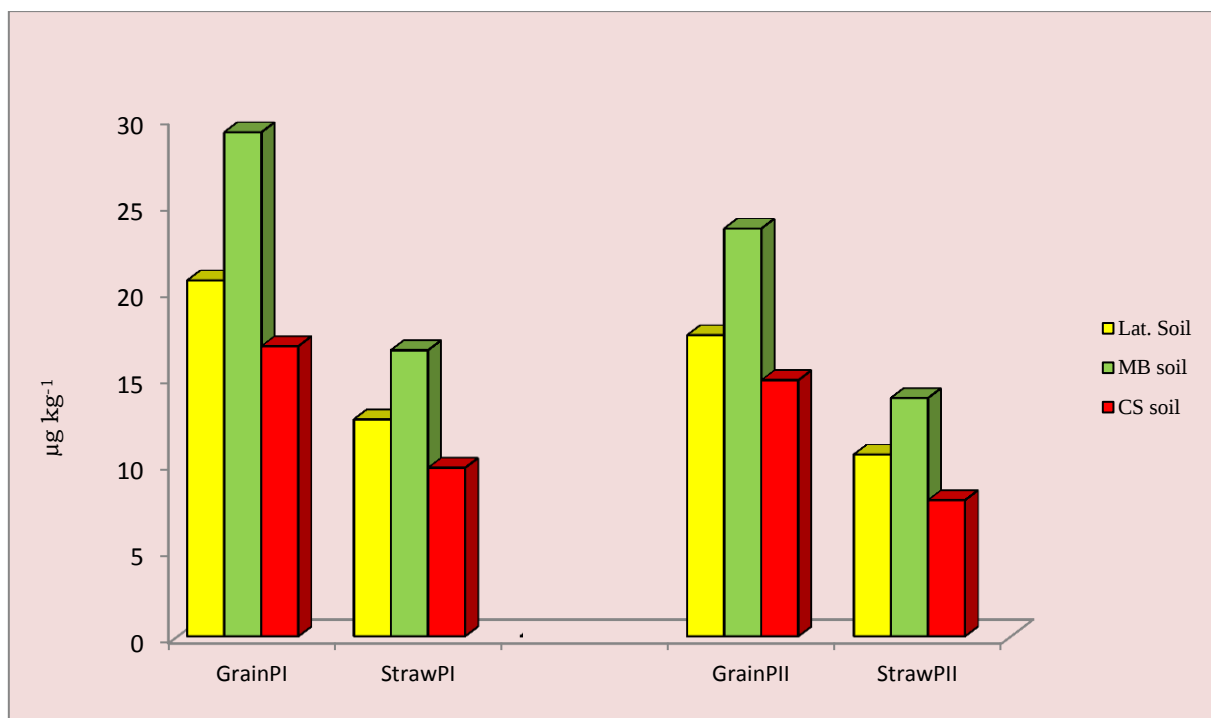
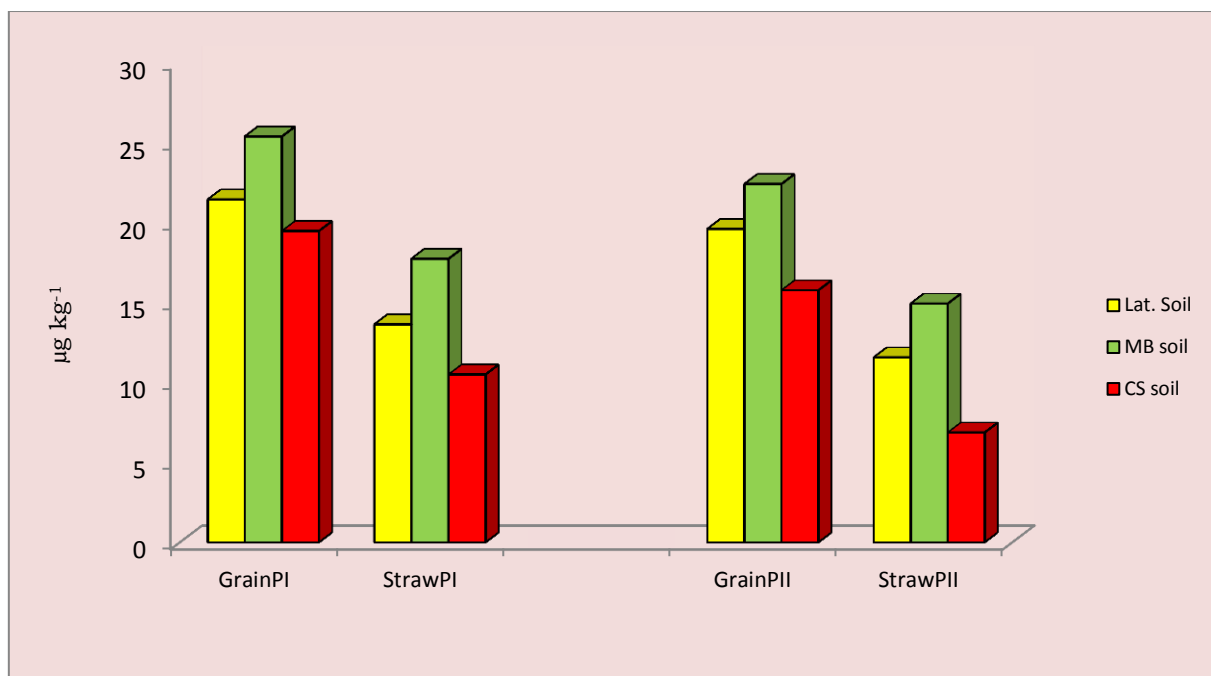


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Lat. soil: Lateritic soil, MB soil: Medium black soil, CS soil: Coastal saline soil PI:Carbofuron, PII:Phorate

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Lat. soil: Lateritic soil, MB soil: Medium black soil, CS soil: Coastal saline soil PI:Carbofuron, PII:Phorate

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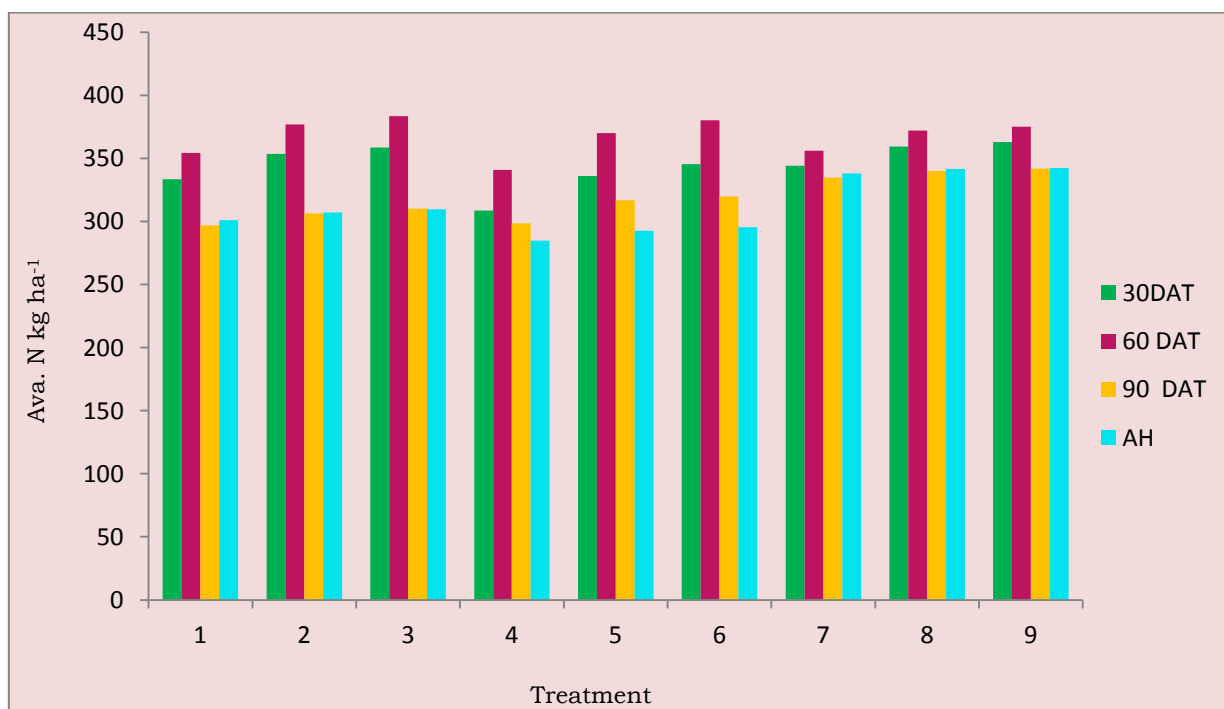


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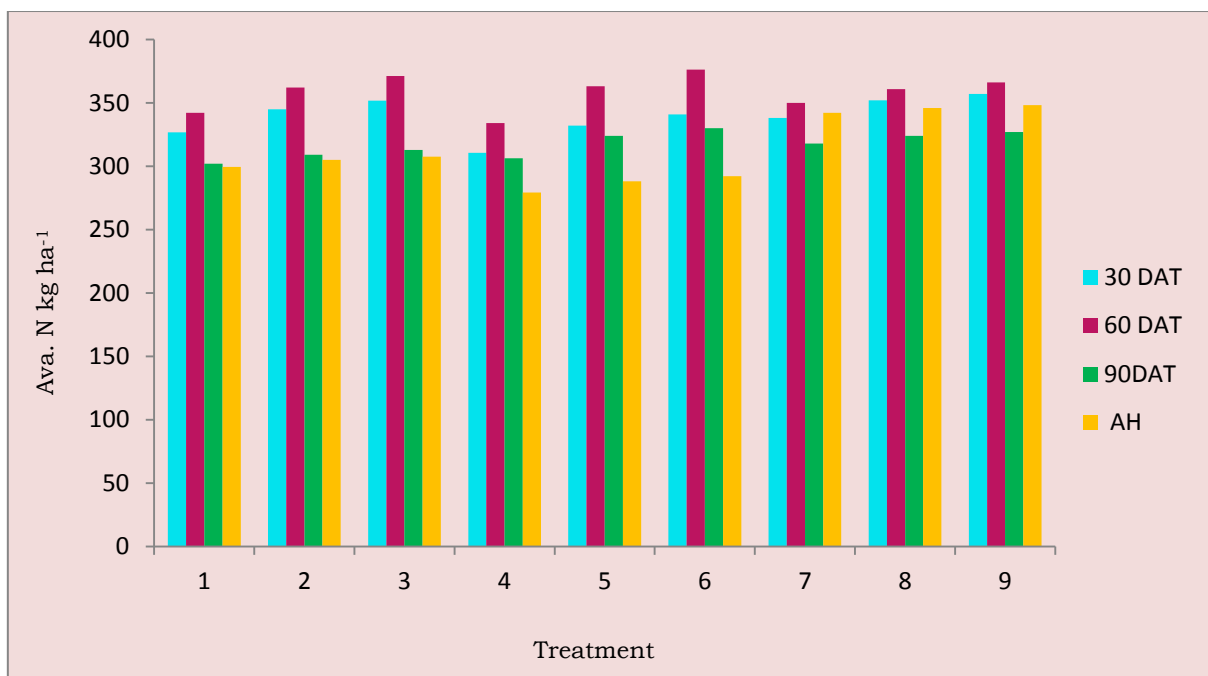


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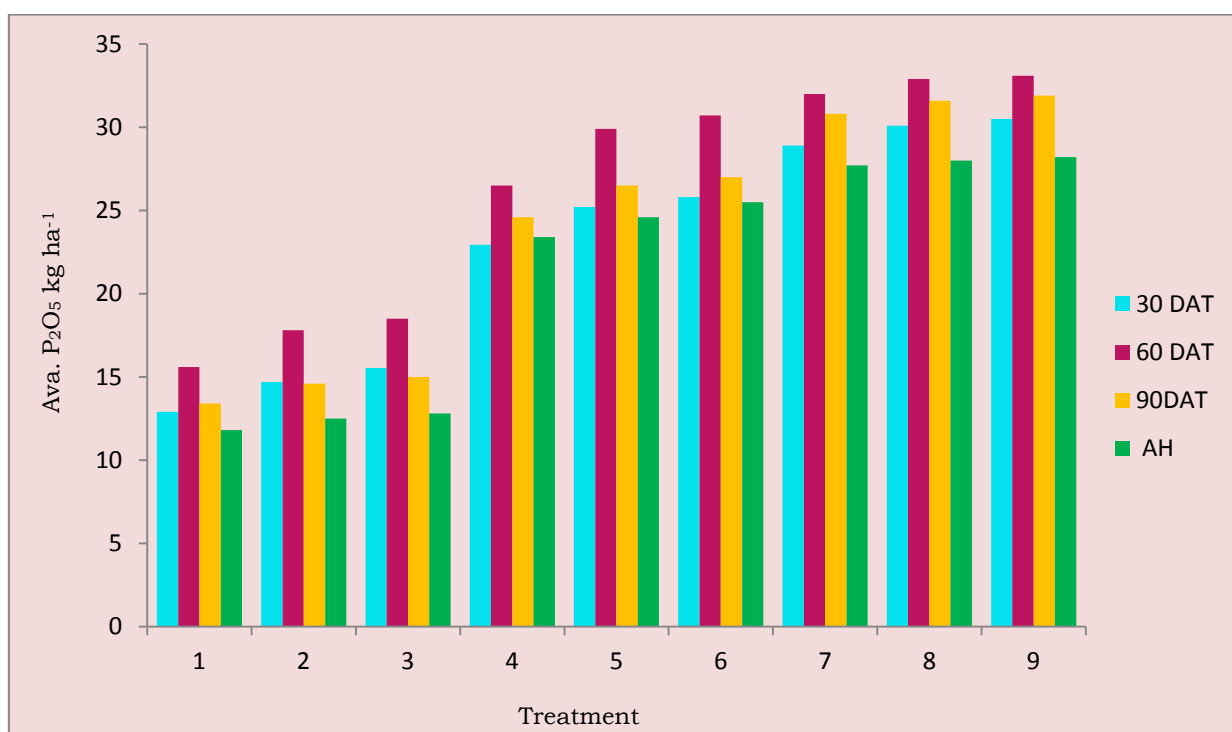


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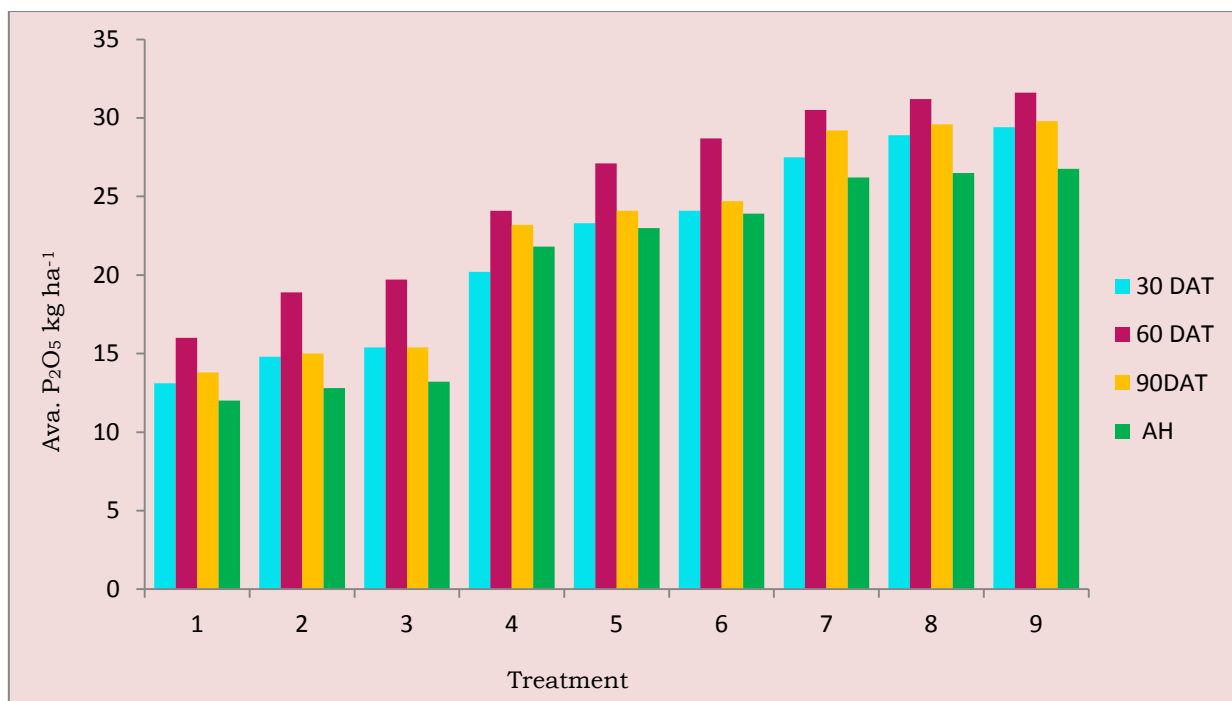


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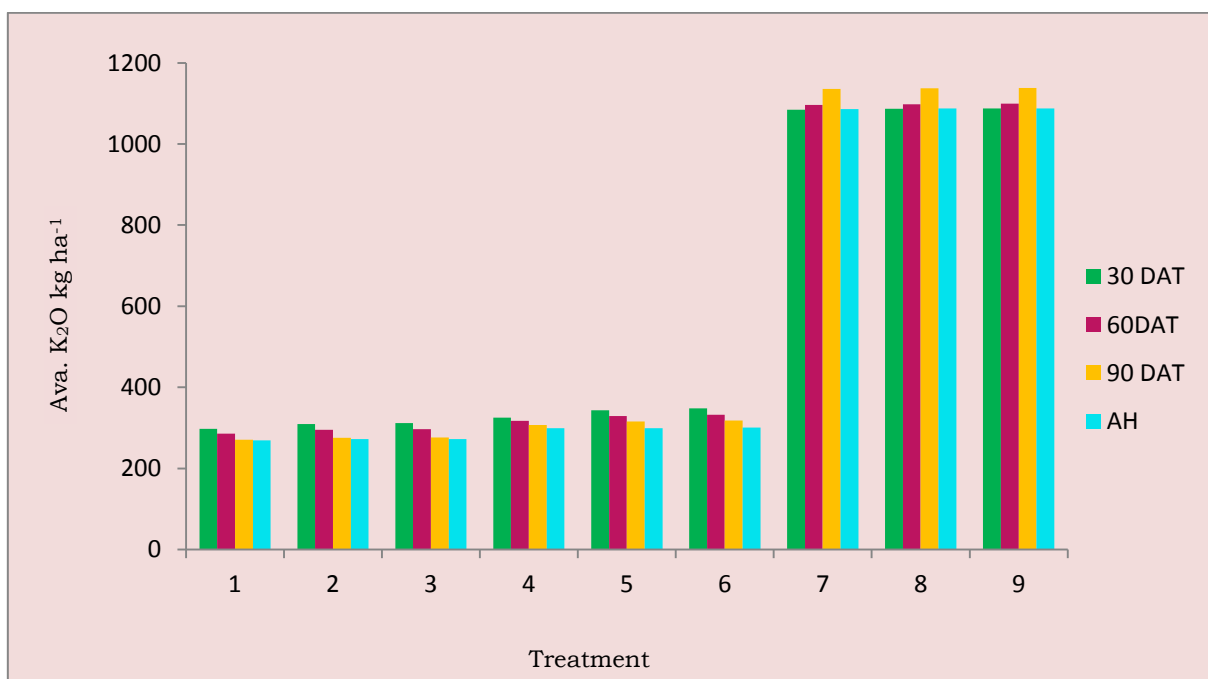


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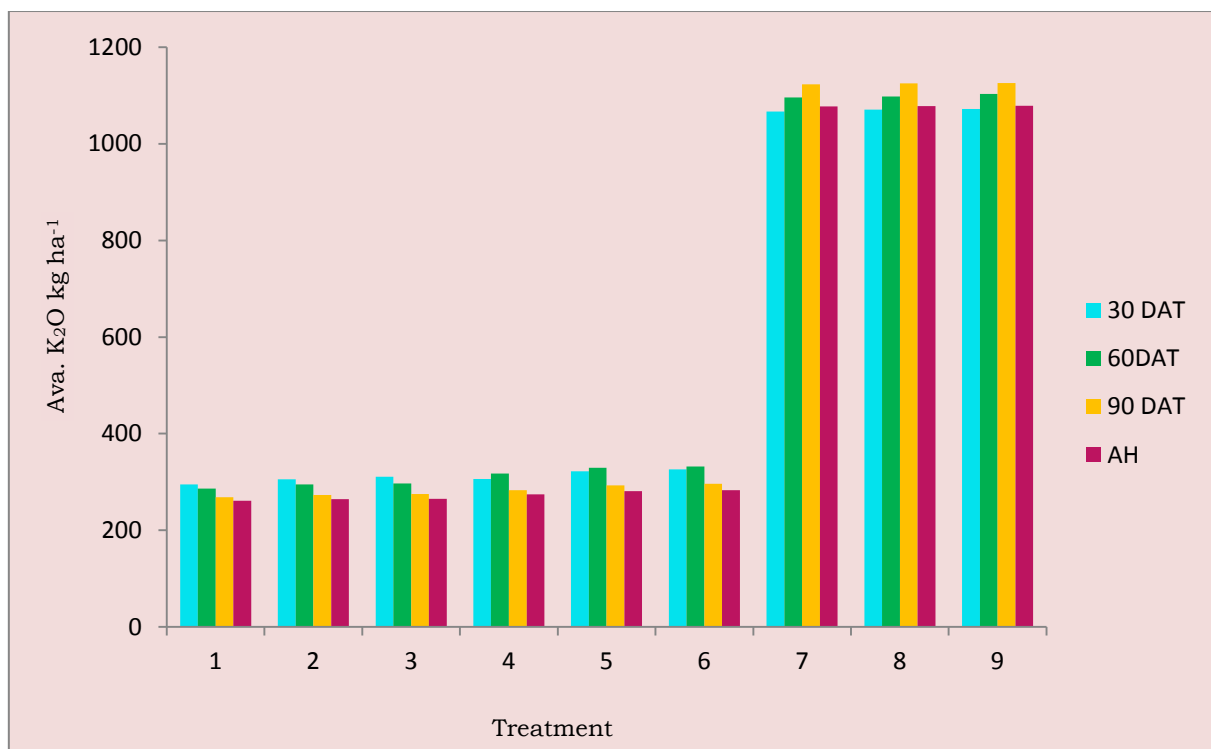


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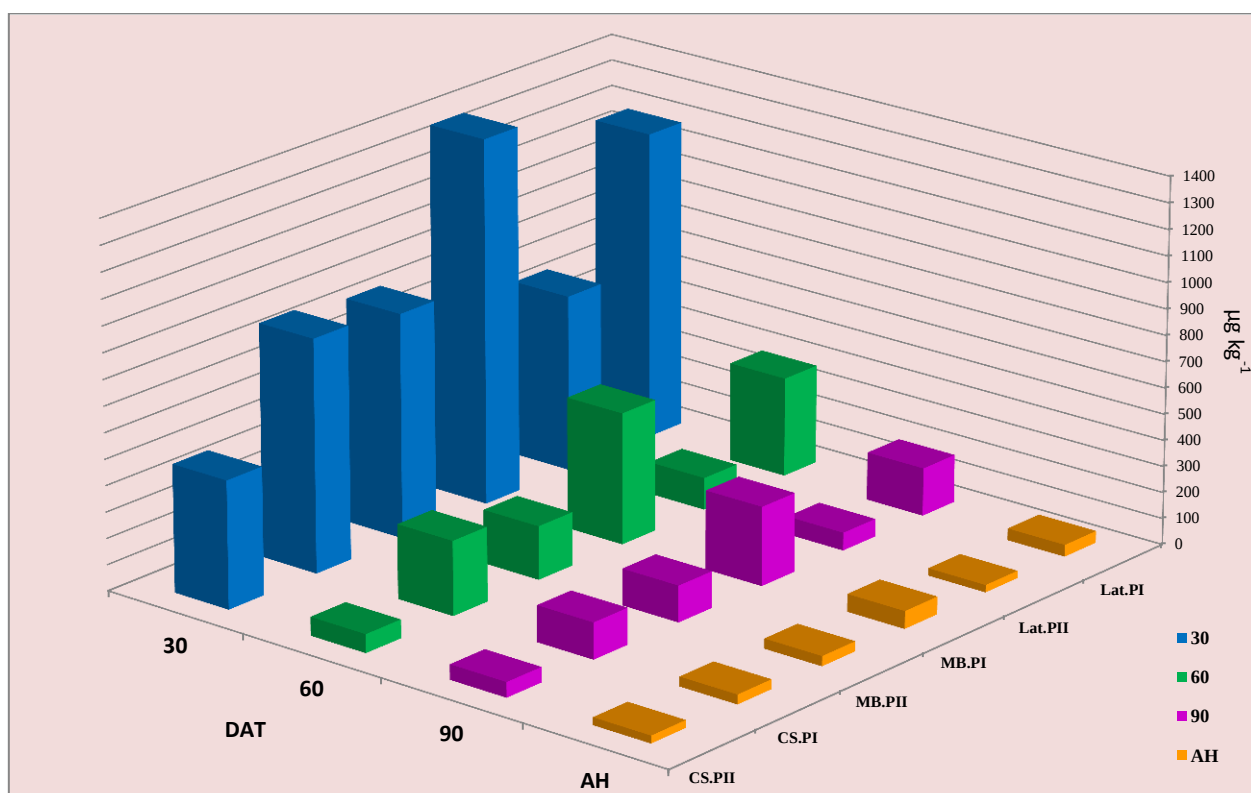


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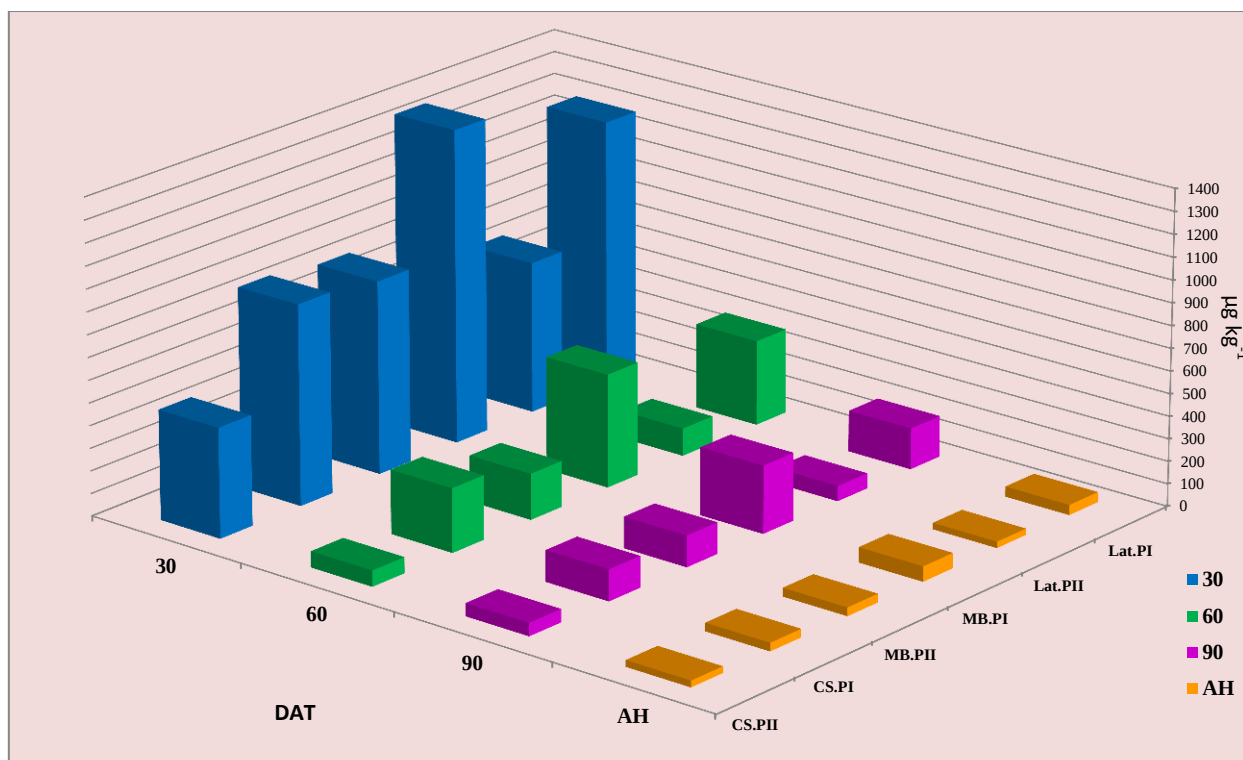


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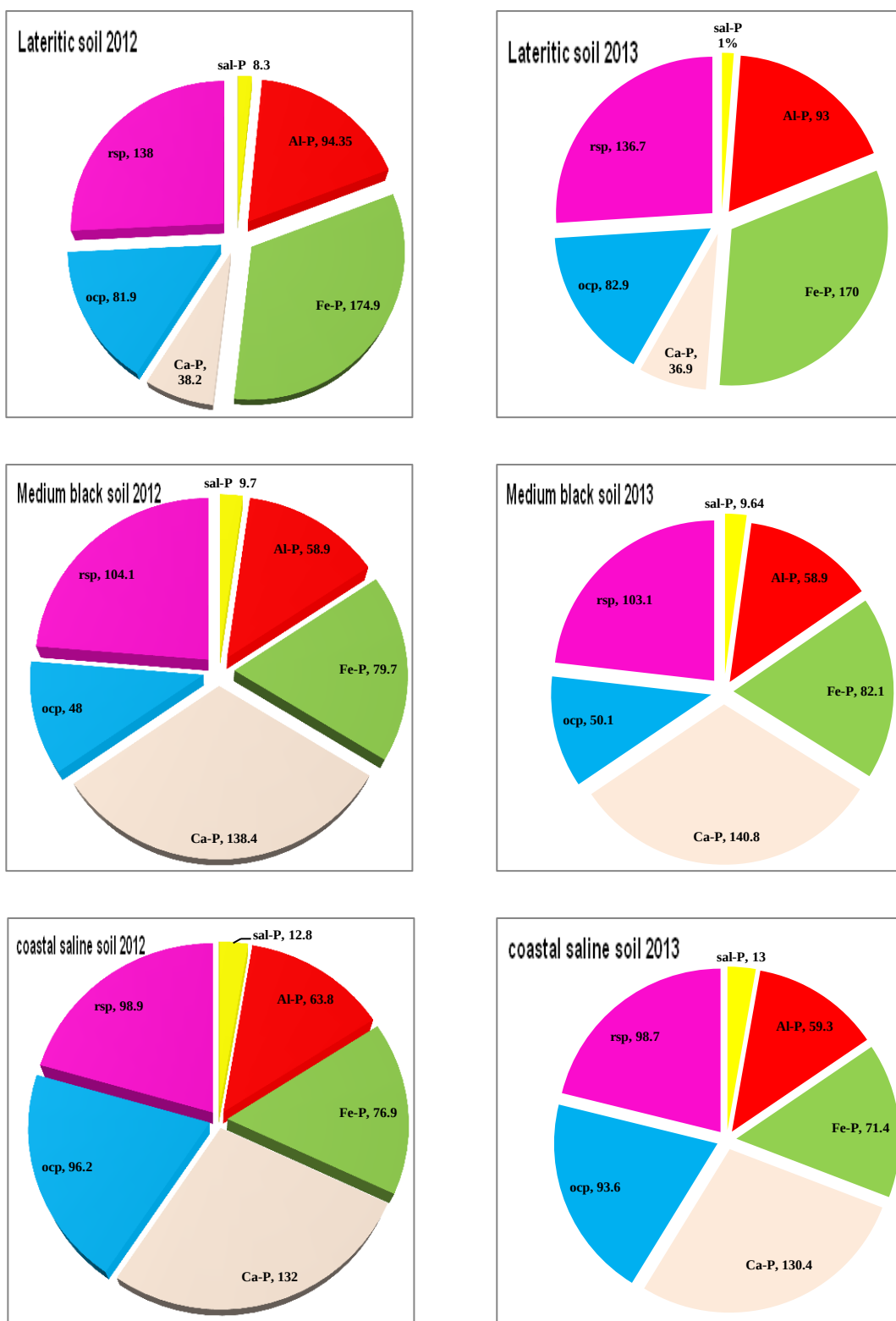


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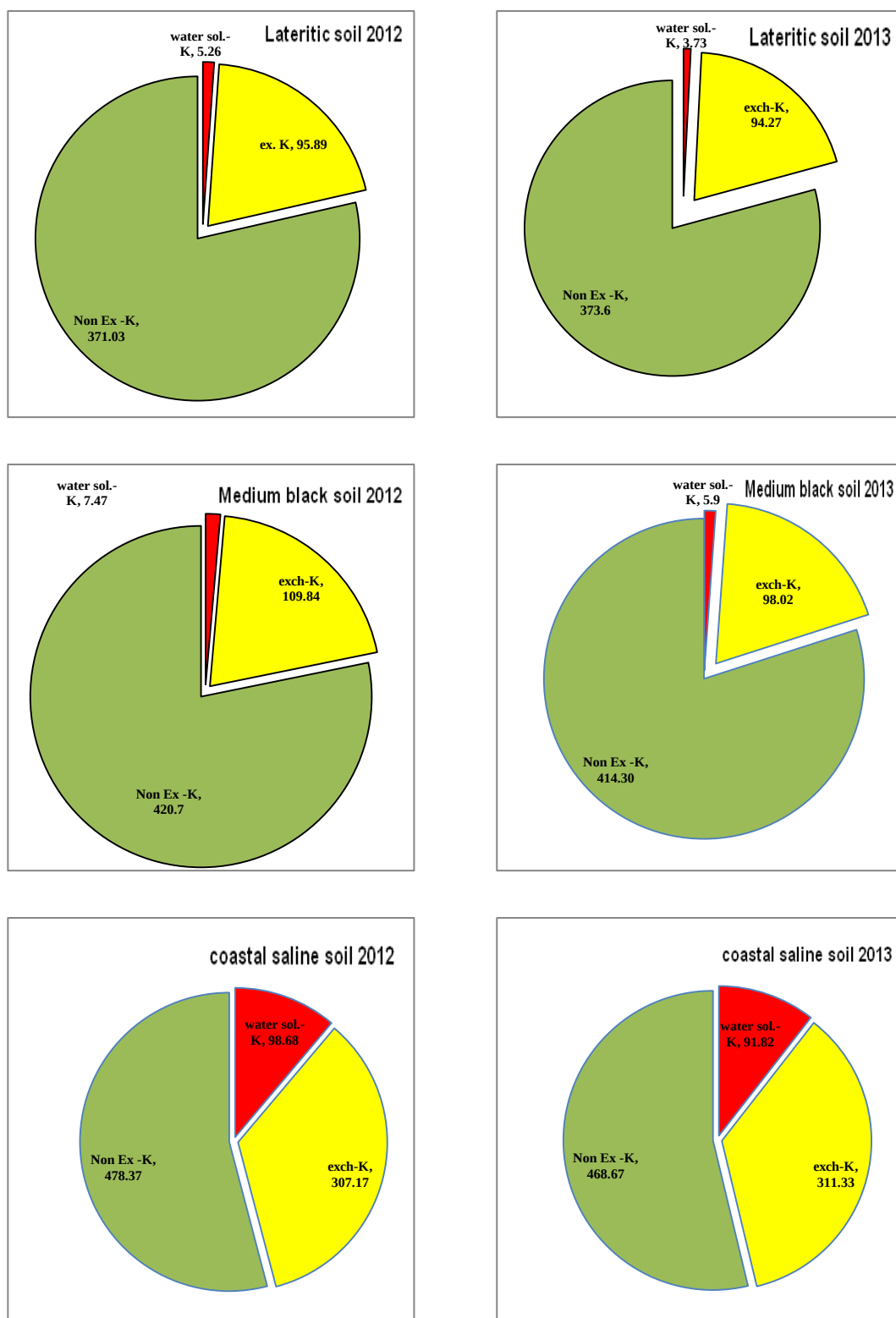


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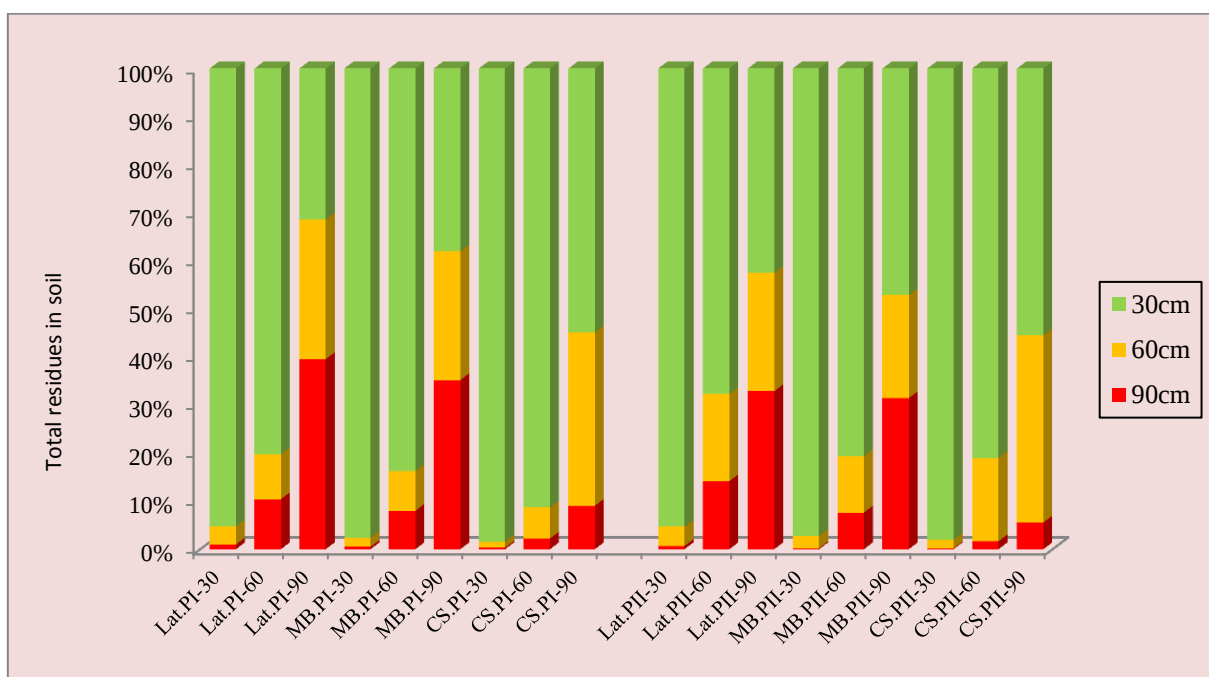


Fig.44: Effect of different treatment on persistence of pesticides at different depth of soil column (2013).

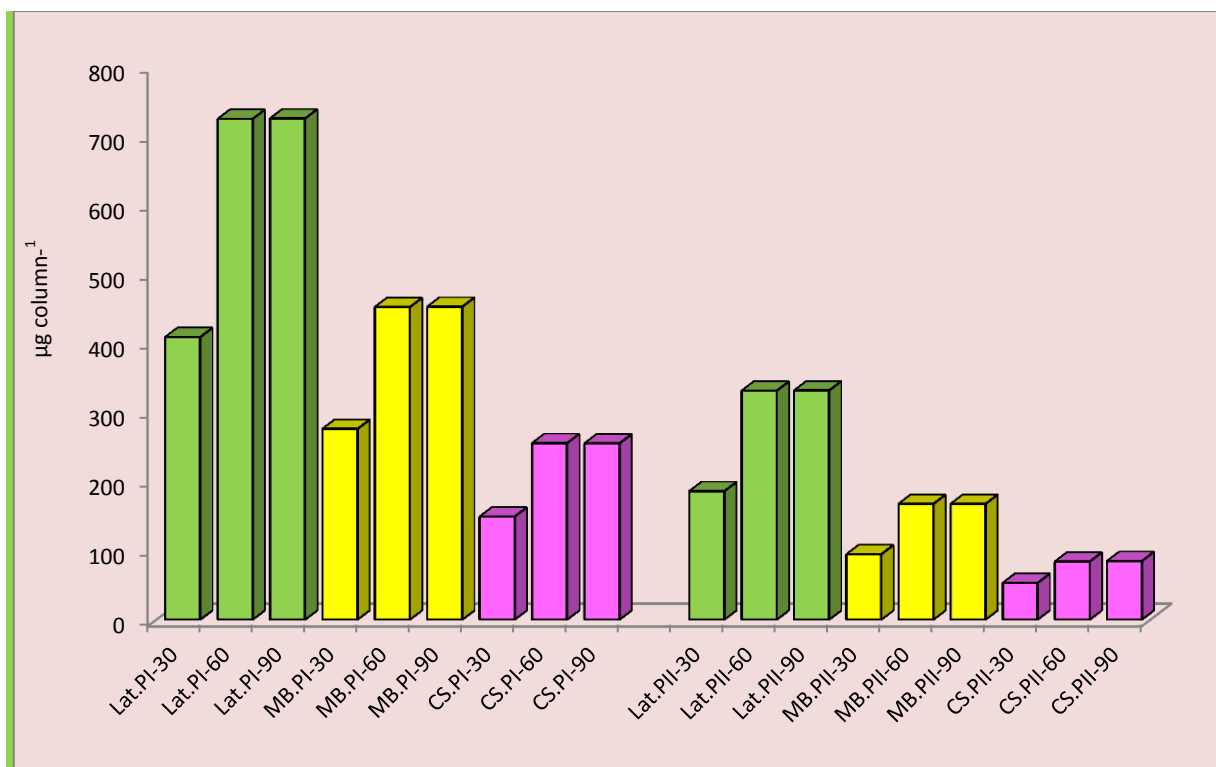


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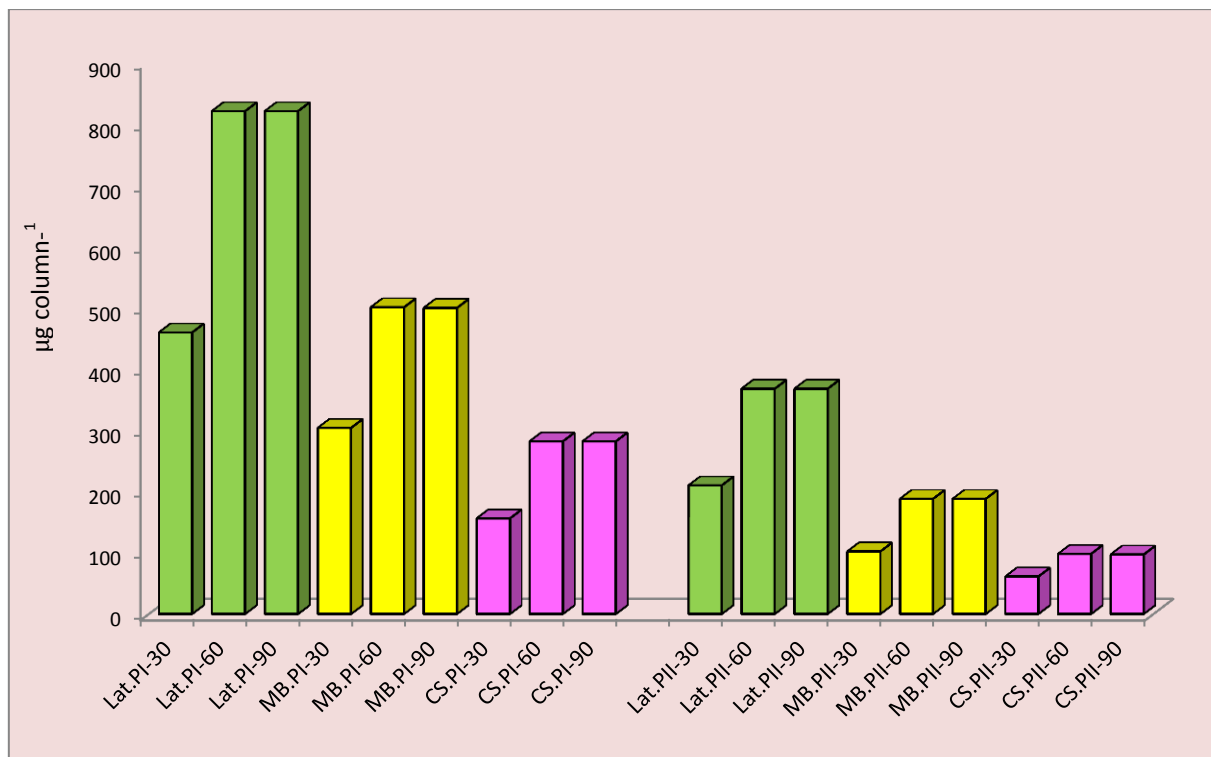


Fig.42: Leaching losses of pesticides from different soil matrices (column) as affected by various treatments. (2013).

CHAPTER-I

INTRODUCTION

Agriculture is the base of Indian economic development and is among the largest agricultural societies in the world. The agricultural sector contributes nearly higher percent of the gross domestic production and it provides livelihood to approximate peoples. Agricultural production has recorded remarkable growth over the past few decades. Though the high yielding varieties and hybrids have contributed significantly towards improving production, these varieties and hybrids are more demanding in terms of water requirement, insecticides and fertilizers. The major problem associated with the growth of agriculture sector is the use of fertilizers and insecticides throughout India. Although, the use of agricultural chemical has produced significant benefits in increasing crop yields, it has also resulted in various 'non target' impacts such as appearance of some fertilizers and insecticides in surface and groundwater toxicity to animals, shift in weed flora and appearance of resistant weed varieties.

NPK are major nutrients required by all the crops for their growth. The fertilizers are required for the nutrient support to the plant growth. When fertilizers are applied to crop as water soluble source do not remain in the soil for longer period and quickly starts getting converted into sparingly soluble or insoluble compounds due to different soil characteristics. The transformation of added fertilizers greatly depends on physical and chemical environment of the soil.

In India, mainly carbamates and organo-phosphate pesticides are used. Besides preventing the losses due to insects, insecticides also affect the populations and activity of beneficial microorganisms in soil. Some insecticides may favorably affect the growth and activities of microorganisms in soil (Das *et al.*, 1995) while others have adverse effects on the growth of soil micro flora. Part of a pesticide application usually reaches the soil, even if sprayed on the growing crop, and so may have an effect on organisms living in the soil leading to affect the fertility of soil. Thus it act also as region of greatest activity of soil fauna and flora and provides a platform for interaction of insecticide residues with them. The indiscriminate use of pesticides disturbs the soil

biological environment leading to infertility of soil. Therefore, it is important to study the possible effects of specific pesticides on availability of nutrients to crops.

It is interesting to note that insecticides frequently applied in modern agriculture mostly belong to the organophosphate and carbamate groups, but their comparative residual effects on nutrients availability under a particular soil conditions have rarely been reported (Das and Mukherjee, 1998a).

Soil plays an important role in water and chemical movement through it. The soil type has a great important influence on nutrient and pesticides leaching losses as the movement of these nutrients and pesticides in water is affected by the soil characteristics which define their retention. The factors known to influence the fate and behaviour of insecticides in soil systems. These are chemical decomposition, photochemical decomposition, microbial decomposition, volatilization, movement, persistence, plant or organism uptake and adsorption. Moreover factors such as composition of soil, physical nature of chemical fertilizers and insecticides, soil reaction, nature of the saturating cations on the soil exchange sites and nature of the formulation directly influence the mobility of these compounds/chemicals in the soil system. The total amount of rainfall or irrigation water received, the intensity (water flux) and frequency of received water, all appear to effect movement of these chemicals in soils. Fertilizers and insecticides can move from their initial distribution by a number of processes. Transport of these may be the result of processes such as, the formation of soluble complexes with soil solution components such as dissolved organic matter and metals or the incomplete interaction of these compounds with the solid state organic or inorganic matter in the soil.

Leaching loss of pesticides and nutrients through soil under crop is the major mean of transport of nutrients. Leaching means vertical downward movement of water due to gravitational force. With percolating water, nutrients and pesticides dissolved in water and water move from the point of application to a deeper horizon of the soil profile. The extent of leaching of primary nutrients and pesticides is determined by the solubility, adsorptive properties and their respective application rate as well as by the water movement in soil due to the different physico-chemical characteristics of the various types of soil. Through this process the nutrients and pesticides can reach the water table and then move with the water table. If nutrients and pesticides are lost in the leaching water, part of the cost of the nutrient input is being lost, as these nutrients and

pesticides are no longer available for the growth of the crop. Thus, there is a one economic aspect to this concern, primarily because nutrients and pesticides input in the form of chemical fertilizers and pesticides are a major cost of production for crops and particularly so for crop production. The loss of major nutrients and pesticides from soil with water during periods of crop growth not only reduces the nutrient use efficiencies but also has the potential for environmental degradation.

Considerable research has been computed on the fate of fertilizers and pesticides for a wider range of crops but few studies have been reported on the availability of NPK to crop in a various soil fertilized at the time of crop growth. The transformation of added fertilizers and pesticides greatly depends on physical and chemical environment of soil. Hence it is very important to understand and study the fertilizers/ insecticides behavior in the soil matrix in order to mitigate their adverse impacts.

An experiment was, therefore, conducted to investigate the effect of Phorate (O,O-diethyl-S-ethylthiomethyl dithiophosphate) and Carbofuran (2,3-dihydro-2,2-dimethyl benzofuran-7-yl-N-methylcarbamate) at their recommended field application rates, on the nutrient availability as well as the persistence of the insecticides in the rhizosphere soils of rice. Since Phorate (an organophosphate) and Carbofuran (a carbamate), the two systemic granular insecticides, are frequently used to combat the insects in rice cultivation, it becomes imperative to evaluate their effects on nutrient availability in rice fields.

The hybrid rice variety 'Sahyadri' in Maharashtra was developed by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli and released for cultivation in 1988. Hybrid rice yields 15–20 per cent higher than the best high yielding varieties of similar duration at the cost of higher nutrient removal. Fulfillment of nutritional requirement of hybrid rice through inorganic fertilizers is not only costly but it also deteriorate the soil and water health, as these soils are more hungry than thirsty. The applied fertilizers and pesticides undergo numerous transformations in soil and water hydrolysis, photolysis, oxidation and reduction are some of the most common transformations.

Fertilizers and pesticides are costly inputs and need to be managed efficiently for higher nutrient recovery returns. The average use of fertilizers in Konkan region

was 60.6 kg (N + P₂O₅ + K₂O) ha⁻¹ during 2001 - 2002 (Anonymous 2002). The fertilizers contribute 50 to 60 per cent in crop yield enhancement.

In India, about 40 percent of the total plant nutrients are consumed by rice crop alone. Though the use of fertilizers per unit area of rice is higher, the Fertilizer Use Efficiency (FUE) is low. Assessment of nutrient transformation, leaching losses and their availability in combination with pesticides could increase yield through increased soil productivity and higher fertilizer use efficiency.

The study undertaken involved three different soils of Konkan region for their different textures, structure and organic carbon content. The results will aid in assessing the impact of these fertilizers and insecticides on the soil matrix under different physico-chemical characteristics of soils. However, it is very challenging to quantitatively describe the transport of these chemicals in field setting and hence its studies have been carried out in pot culture and columns.

Combined application of fertilizers and pesticides unfailingly at their recommended dose sustained productivity. Therefore, the present investigation viz., “Movement behaviour of primary nutrients, carbamates and organophosphate based insecticides in different soil matrices” was undertaken with the following objectives:

1. To study the dynamics of primary nutrients in different soil types under rice crop.
2. To study the persistence of carbamate and organo-phosphate based insecticides in different soil types.
3. To study the correlation of primary nutrients and insecticides with physico-chemical properties of soils.
4. To study the periodical persistence of insecticides in the soil profiles.

CHAPTER III

MATERIALS AND METHODS

The present investigation pertaining to the studies on the “movement behaviour of primary nutrients, carbamate and organophosphate based insecticides in different soil matrices” was conducted during *Kharif*, 2012 and 2013 at the glasshouse of College of Agriculture, Dapoli, Dist. Ratnagiri. The analytical work was done in the research laboratory of Department of Soil Science and Agricultural Chemistry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri. The details regarding materials used and the methods followed during the course of the present investigation are presented in this chapter.

3.1 Material

3.1.1 Soil, climate and topography

The picturesque landscape of Western Ghats stretching from Daman in North to Terekhol creek in south is defined as Konkan. The domain of the present research work is the Konkan region of Maharashtra state. The Konkan region is located between $15^{\circ} 44'$ and $20^{\circ} 20'$ N latitude and $70^{\circ} 10'$ and $74^{\circ} 05'$ E longitude. The spread of Konkan is 30846 sq. km. comprising Greater Bombay, Thane, Raigad, Ratnagiri and Sindhudurg districts. The region has warm and humid climate with an average rainfall of 2515 to 3625 mm. Arabian sea coastline of 720 km on the west with a background of coastal strip of land bounded by Sahyadri hills on the east state the geographical characteristics of Konkan. The temperature of the region

ranges from a maximum of 37°C to a minimum of 15°C. Konkan region is broadly divided into three agroclimatic zones viz. very high rainfall zone with Lateritic soil, very high rainfall zone with non-lateritic soil and ghat zone.

The first zone includes the laterite and lateritic soils which occupy whole Ratnagiri district and southern portion of Raigad district. The soils are developed from basalt by process of laterization. The soils are acidic in reaction due to leaching of bases. In general, poor in fertility and have high P-fixing capacity. .

The second zone comprises whole of Thane and remaining northern part of Raigad district. The soils of these zones are Medium black and neutral to slightly alkaline in reaction. They contain free calcium carbonate and are poor in phosphorous content, medium to high in nitrogen and potassium contents.

The soils along the west coast of the Konkan (Panvel) is known as Coastal saline soil and it covers an area of about 65,465 ha (Report of the *Khar* Land Development committee, 1982). The alluvium is mostly derived from trap and the soils are impregnated with salts to a varying degree according to their location in respect to sea. The soils in immediate vicinity of sea are highly saline inspite of rainfall. The texture of Coastal saline soils ranges from clay loam to clay.

3.1.1.1. Collection and preparation of soil samples:

In order to represent these three distinct zones of Konkan, three representative soil profiles samples, one each from Lateritic, Medium black and Coastal saline soil were collected from different tahsils of Konkan namely Dapoli, Karjat and Panvel. All the locations are the Agricultural Research centers of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. At each location one rice growing soil profile was selected. From each of the mentioned locations, one profile sample (0-30cm, 30-60cm and 60-90cm) collected by following standard procedure of soil sample collection. The details of the locations from which the soil samples were collected are presented in Table 1.

Table 1. Details of the locations of rice field and number of soil samples collected

Location No.	Soil type	Location	Name of the sub-location
I	Lateritic soil	Dapoli	Agronomy Department, College of Agriculture, Dapoli, Dist. Ratnagiri
II	Medium black soil	Karjat	Agriculture research station, Karjat, Dist.

			Raigad
III	Coastal saline soil	Panvel	<i>Khar</i> Land Research Station, Panvel, Dist. Raigad

Total Number of Soil Samples = 9 Samples

Note: From each location one profile soil sample (0-30, 30-60 and 60-90cm) was collected.

To know the initial soil fertility status the collected soil samples were processed for analysis. All the profile samples were air dried under shade in an open room. Then the impurities like stones, pebbles, roots, dried leaves etc. were removed. After that, the soil samples were grinded in wooden mortar and then sieved through 2 mm and 0.5 mm sieve for special determination like soil organic carbon. The processed surface soil was used for conducting a pot culture experiment while leaching column experiment was conducted with using soil samples at different depth (0-30cm 30-60cm and 60-90cm) of profile.

3.2 Details of the experiments:

In the present investigation the experiments were laid out in two sets. The experiment in glass house was conducted during *Kharif*, 2012 and 2013. With surface soil samples, one set of experiment was subjected to study leaching losses of NPK and pesticides from rice growing pots in the experiment- I while the other set of experiment with soil samples at various depth, study was subjected to leaching losses of pesticides as well as their movement and distribution using soil column were carried out without rice. (Experiment-II)

3.2.1 Experiment-I:

Pot culture experiment was conducted in plastic pots of 10 kg capacity having 30 cm diameter and 45 cm height. These pots were placed at the bottom with a hole to collect leachates. The plastic pots were first thoroughly cleaned with water and then rinsed with distilled water before filling of the soil. Small quantities of pebbles were put at the bottom of the pots and ten kg of soil was filled in each pot. Treatment wise fertilizers were added and mixed thoroughly. The experiment were laid out separately in CRD design with nine treatments and replicated three times for each set of experiments.

Layout plan of pot culture experiment

- 1) Soil type : Lateritic, Medium black and Coastal Saline soil
- 2) Year and season of experiment : *Kharif*, 2012 and 2013

- 3) Test Crop : Rice
- 4) Variety : Sahyandri-4
- 5) Number of treatments : 9
- 6) Number of replications : Three
- 7) Total number of pots : 27
- 8) Design of experiment : C.R.D.
- 9) Weight of soil per pot : 10 kg

3.2.1.1 Crop

The hybrid rice variety Sahyadri-4, released by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli in 2008 was taken as a test crop during *Kharif* 2012 and 2013. Sahyadri-4 is mid-late (115 to 120 days) in duration, having long slender grain with 90 to 120 cm plant height, non-lodging, non-shedding and has yield potential of about 6.5 to 7.0 tons per hectare.

3.2.1.2 Details of treatment

There were nine treatment combinations in three replication. The details are presented in Table 2.

Table 2 : Details of the treatments for Experiment-I

Treatment No.	Description of Treatment
T₁	Lateritic soil +RDF
T₂	Lateritic soil +RDF + P ₁
T₃	Lateritic soil + RDF + P ₂
T₄	Medium Black soil + RDF
T₅	Medium Black soil + RDF + P ₁
T₆	Medium Black soil + RDF + P ₂
T₇	Coastal saline soil +RDF
T₈	Coastal saline soil +RDF + P ₁
T₉	Coastal saline soil +RDF + P ₂

Note: RDF - Recommended dose of fertilizer i.e. NPK @ 150:50:50 through

SSP - Single Super Phosphate, MOP - Muriate of Potash

P₁: Carbamates insecticide: Cabofuron3G@recommended dose (16.5kg ha⁻¹)

P₂: Organophosphates insecticide: Phorate10G @ (10.0 kg ha⁻¹)

3.2.1.3 Application of manure and fertilizers

The recommended dose of NPK treatment dose @150:50:50 were applied through urea, SSP and MOP. The compositions of inorganic fertilizers used in the present study are given in Table 3.

Table 3: Nutrient composition of various inorganic fertilizers and pesticides used in the study.

Sr. No.	Name of fertilizer	Composition (%)		
		N	P ₂ O ₅	K
1.	Urea	46.0	-	-
2.	Single Super Phosphate	-	16.0	-
3.	Muriate of Potash	-	-	60.0

Nitrogen @ 150 kg ha⁻¹ was applied in three splits viz., first dose of 40 per cent N at the time of transplanting, second dose of 40 percent 30 days after transplanting and third dose of 20 percent 60 days of transplanting. Phosphorus @ 50 kg ha⁻¹ and potassium @ 50 kg ha⁻¹ were applied in a single dose at the time of transplanting as per the treatments. The plant nutrients were applied through fertilizer viz., urea, single super phosphate and muriate of potash for N, P and K respectively.

Pesticides PI (Carbofuron3G) @ recommended doze of 16.5 kg ha⁻¹ and pesticide PII (Phorate10G) @ recommended doze of 10.0kg ha⁻¹ was applied as basal doze at the time of transplanting to each pot calculated on the basis of 10 kg soil per pot.

On the basis of rate of application, the quantity of various fertilizers and pesticides required for each pot as per the treatments were calculated and applied to the crop.

3.2.1.4 Details of cultivation

1. Seedlings used for experiment

The seedlings of rice crop (variety Sahyandri-4) were collected from the farm of Dept of Botany, College of Agriculture, Dapoli. 21 days old rice seedlings were used for transplanting.

2. Transplanting

The soil in the pots was puddle by hand and by adding water, before transplanting. After puddling and mixing of basal dose of fertilizer in soil, twenty one days old rice seedlings (Variety Sahyandri-4) were transplanted. The soil was kept submerged (under 2.5 cm water) throughout the crop growth period.

3. Cultural operations

The various cultural operations were undertaken as and when required, the details regarding cultural operations and their dates as well as collection of soil and plant samples is given in Table 4.

Table 4 : Schedule of cultural operation performed for experiment-I

Sr. No.	Field operations	Date	
		<i>Kharif 2012</i>	<i>Kharif 2013</i>
1.	Pot culture operation		
	a. Filling of pots	22.06.2012	24.06.2013
	b. Puddling	23.07.2012	27.07.2013
	c. Application of 40 per cent dose of N and full dose of P ₂ O ₅ and K ₂ O	23.07.2012	27.07.2013
	d. Transplanting	24.07.2012	29.07.2013
	e. Application of 40 percent dose of N	24.08.2012	30.08.2013
	f. Application of 20 percent dose of N	24.09.2012	30.09.2013
	g. Application of 100 per cent dose of Phorate10G and Carbofuron 3G by broadcast method	14.08.2012	19.08.2013
2	Lecheate collection		
	a) 0-30 DAT	25.07 to 26.08.2012	29.07 to 29.08.2013
	b) 30-60 DAT	27.08 to 27.09.2012	30.08 to 30.09.2013
	c) 60-90 DAT	28.09 to 28.10.2012	01.09 to 01.10.2013
3.	Collection of soil and plant samples		
	i) Soil sampling		
	a) Soil sampling at 30 DAT	24.08.2012	29.08.2013
	b) Soil sampling at 60 DAT	25.09.2012	30.09.2013
	c) Soil sampling at 90 DAT	25.10.2012	30.10.2013
	d) Soil sampling at harvest	15.11.2012	19.11.2013
	ii) Plant sampling		
	e) Plant sampling at harvest	15.11.2012	19.11.2013
4.	Harvesting	15.11.2012	19.11.2013
5.	Processing		

	a) Threshing	21.11.2012	24.11.2013
6.	Recording yield data		
	a) Grain yield	22.11.2012	24.11.2013
	b) Straw yield	22.11.2012	24.11.2013

Note: The leacheate were collected at 7 days interval which were preserved and pooled for analyzed of the pesticides content.

4. Crop harvesting and threshing

The crop was harvested at its optimum maturity stage when the leaves turn yellow. Threshing was done manually after adequate sun-drying of the produce. Treatment wise grain yield and straw data were recorded.

3.2.1.5 Biometric observations

In order to study the effect of various treatments on the growth parameters, yield, primary nutrient content, pesticide content, primary nutrients and pesticides uptake by rice and primary nutrient and pesticides persistence in soil, were recorded from time to time.

1. Sampling techniques

For recording biometric observations hills from each treatment pots were selected. The selected samples were labelled with proper notations.

3.2.1.6 Growth parameters

The details in respect of various biometric and other observations recorded during the course of study are presented in Table 5.

1. Plant height (cm)

Plant height was recorded from hills and then the average was worked out. Height of plant was measured in centimeter from the ground level to the tip of fully opened leaf.

2. Number of leaves (per plant)

Number of leaves, were recorded from hills and then the average was worked out. Number of leaves, were measured including older leaves to new emerging leaf.

3. Number of tillers (per plant)

The periodical total number of tillers produced plant⁻¹, were counted from representative hills and the average was worked out.

3.2.1.7 Yield of the crop

Crop was harvested at maturity and threshed. The grain and straw yield obtained after threshing. The produce from each pot was sun dried for about 5 to 6 days. After sun drying of the produce, treatment wise grain and straw yield of rice was recorded and yield data expressed in g pot⁻¹.

Table 5 : Biometric and other observations recorded of experiment -I

Sr. No.	Particulars	Frequency	Stages
A.	Growth and yield a) Plant height (cm) b) Number of leaves pot ⁻¹ c) Number of tillers pot ⁻¹	3 3 3	30, 60DAT and AH 30, 60DAT and AH 30, 60DAT and AH
B.	Nutrient content and uptake of N, P and K	1	at harvest
C	Content of pesticides (PI and PII)	1	at harvest
D.	Soil changes in available N, P, K,	4	30, 60, 90 DAT and at harvest
E	Soil changes in pesticides residues (PI and PII)	4	30, 60, 90 DAT and at harvest
F	Soil changes in N, P and K fraction	1	at harvest
D.	a) Grain yield b) Straw yield	1 1	at harvest at harvest

Note: DAT - Days after Transplanting

AH - At harvest

3.2.1.8 Content and uptake of nutrients by rice

In order to know the pattern of content and uptake of nutrients and pesticides by rice, treatment wise plant samples were collected at harvest. The samples were first washed with tap water and with deionised water and then were air dried and preserved in the brown paper bag labelled with permanent marker. These representative samples were adequately dried in oven at a temperature of $60 \pm 5^{\circ}\text{C}$ and ground in Willey type grinding machine and stored in polythene bags for analysis. The samples were then analyzed to know the content and the uptake of nutrients and pesticides.

3.2.1.9 Collection and preparation of soil samples and Changes in nutrient availability

In order to know the effect of various treatments on soil properties periodical soil samples (0-22 cm) were collected from each treatment pot at 30, 60, 90 days after transplanting and at harvest. Treatment wise composite soil samples were prepared by

principle of quartering. The samples were air dried in shade, pounded in wooden mortar with pestle and sieved through 2 mm sieve. After processing, the samples were stored in properly labeled corrugated boxes and used for determination of nutrient (N, P and K) and pesticides (PI and PII) residues availability in the laboratory by following the standard analytical methods.

3.1.2. Experiment-II :

The Experiment-II was conducted by using the profile soils packed in the column according to the depth of 0-30cm, 30-60cm and 60-90cms. The leaching losses of pesticides as well as their movement and distribution in profile of different soil types using soil column were carried out. Experiment-II was conducted in column in absence of any crop so as to study the movement behaviour of the pesticides without crop. With the purpose to reduce the effect of crop in movement, distribution as well as leaching losses of pesticides, the leaching column experiment was set up without rice crop.

Leaching column experiment was conducted in Plexiglass column of 1 kg capacity having 90 cm height and 4.5 cm diameter. Plexiglass column was filled up with soil layers at different depth (0-30 cm, 30-60 cm and 60-90 cm) as per treatment from various soil profiles. Filter paper pieces will be placed on the surface, inside the column to provide uniform distribution of water. Column were shaken and tapped during filling and saturated with water to aid in soil compaction. Soil filled columns were kept in the upright position during saturation with water from the top of the column and during leaching of the pesticide. A time controller syringe pump was used to apply an intermittent pulse of water to the top of the column. Soil column were kept for 30, 60 and 90 day for collecting the percolates used for study as per treatment.

Applications of insecticides at the top of column as per the treatment were done. Application of water was done through time controller syringe pump. Periodical percolates were collected in glass flask for analysis. Collected percolates preserved with preservatives in amber coloured glass bottle for analysis. The details regarding the treatment to leaching column are presented in Table 6. The experiment were laid out separately in FCRD design with nine treatments and replicated three times for each set of experiments.

Table 6: Details of the treatments for experiment-II (Leaching column without rice crop)

Treatments	Treatments details	
T ₁	Lateritic soil + PI + 30DAA	Lateritic soil + PII + 30DAA

T ₂	Lateritic soil + PI + 60DAA	Lateritic soil + PII + 60DAA
T ₃	Lateritic soil + PI + 90DAA	Lateritic soil + PII + 90DAA
T ₄	Medium black soil+ PI + 30DAA	Medium black soil + PII + 30DAA
T ₅	Medium black soil+ PI + 60DAA	Medium black soil + PII + 60DAA
T ₆	Medium black soil+ PI + 90 DAA	Medium black soil + PII + 90DAA
T ₇	Coastal saline soil+ PI + 30DAA	Coastal saline soil + PII + 30DAA
T ₈	Coastal saline soil + PI + 60 DAA	Coastal saline soil + PII + 60DAA
T ₉	Coastal saline soil + PI + 90 DAA	Coastal saline soil + PII + 90 DAA

PI: Carbamates insecticide: Cabofuron3G @ 7366.0 ug column⁻¹)

PII: Organophosphates insecticide: Phorate10G @ 4464.0 ug column⁻¹)

3.1.2.1 Leaching losses of pesticides from leaching column

In order to know the pattern of leaching losses of pesticides from leaching column treatment wise leachate were collected at seven days interval and leachate were pooled for analysis of pesticides. Soil column were kept 30, 60 and 90DAA as per treatments for collecting the percolates were used for study. The leachate were preserved with preservatives in the brown colored bottle and labelled with permanent marker. The leachate were then analyzed to know the content of pesticides. Schedule of operation performed during leaching column experiment was recorded in Table 7.

Table 7. : Schedule of operation performed and observation taken during leaching column experiment

Sr. No.	Field operations	Date	
		First year	Second year
1.	Leaching Column Experiment		
	a) Filling of column	22.12.2012	25.11.2013
	b) Tapping of column	28.12.2012	27.12.2013

	c) Setting of time controller syringe pump for water application	02.01.2013	05.01.2014
	d) Application of pesticides (PI & PII) by broadcasting method	04.01.2013	05.01.2014
2	Collection of leacheate samples		
	a) 0-30 DAA	05.01 to 05.02.2013	05.01 to 05.02.2014
	b) 30-60 DAA	06.02 to 06.03.2013	06.02 to 06.03.2014
	c) 60-90 DAA	07.03 to 07.04.2013	07.03 to 07.04.2014
3.	Cutting of column for soil sampling at various depth of profile		
	a) at 30 DAA	05.02.2013	05.02.2014
	b) at 60 DAA	06.03.2013	06.03.2014
	c) at 90 DAA	07.04.2013	07.04.2014
4	Soil sampling at different depth of profile		
	A) Soil sampling at 30DAA	05.02.2013	05.02.2014
	a) at 0-30cm		
	b) at 30-60cm		
	c) at 60-90cm		
	B) Soil sampling at 60DAA		
	a) at 0-30cm	06.03.2013	06.03.2014
	b) at 30-60cm		
	c) at 60-90cm		
	C) Soil sampling at 90DAA		
	a) at 0-30cm		
	b) at 30-60cm		
	c) at 60-90cm	07.04.2013	07.04.2014

3.1.2.2 Collection and preparation of soil samples from leaching column:

The soil was sampled at different depth (0-30cm, 30-60cm and 60-90cm) by cutting the columns at 30, 60 and 90 DAA as per treatment. After processing, the samples were stored in properly labeled and used for determination of pesticides residues in the laboratory by following the standard analytical methods.

3.3 Methods of analysis

3.3.1 Soil analysis

3.3.1.1 Soil physical properties

i) Bulk density

Bulk density of the field soil samples collected was determined using clod coating method described by (Black, 1965).

ii) Porosity

The porosity was calculated by using the following relationship as described by Black (1965).

$$\eta = (dp - db) \times 100 / dp$$

where, η = Porosity (%)

dp = Particle density (Mg m^{-3})

db = Bulk density (Mg m^{-3})

It was determined by Black's formula as described by Black (1965)

iii) Infiltration rate

It was determined by using Double ring infilterometer method as described by (Jaiswal, 2004).

3.3.1.2. Soil chemical properties

i) Soil reaction

The pH of soil was determined using pH meter having glass and calomel electrode using 1:2.5 soil:water suspension ratio (Jackson, 1973).

ii) Electrical conductivity

Electrical conductivity of soil was determined with the help of Systronic Conductivity Meter-306 using 1:2.5 soil:water suspension ratio (Jackson, 1973).

iii) Organic carbon

It was determined by following Walkley and Black wet oxidation method (Black, 1965).

iv) Organic matter:

It was determined by using Van Bemjmelen factor . (Black, 1965)

v) Available nitrogen

Available nitrogen was determined by alkaline permanganate (0.32% KMnO_4) method (Subbiah and Asija, 1956).

vi) Available phosphorus

Available phosphorus was determined by extracting the soil P with 0.5 M NaHCO_3 at pH 8.5. The soil: extractant ratio was 1:20 and shaking time was 30 minutes. Phosphorus in the extract was determined colorimetrically by using Spectrophotometer as per soil type as outlined by Olsen *et al.*, (1954) and Brays-I method (1945).

viii) Available potassium

It was estimated on Systronics Flame Photometer-128 using neutral-normal-ammonium acetate (NH_4OAc , pH 7.0) as per procedure given by Jackson (1973).

ix) DTPA extractable Zn, Cu, Fe and Mn

The extracting solution used for this purpose consisted of 0.005 M DTPA (Diethylene Triamine Pentacetic Acid), 0.01 M CaCl_2 and 0.1 M TEA (Tri Ethanol Amine) buffered at pH 7.3 (Lindsay and Norwell, 1978). The concentration of these nutrients was read in atomic absorption spectrophotometer.

viii) Cation exchange capacity: $[\text{Cmol (P}^+) \text{ kg}^{-1}]$:

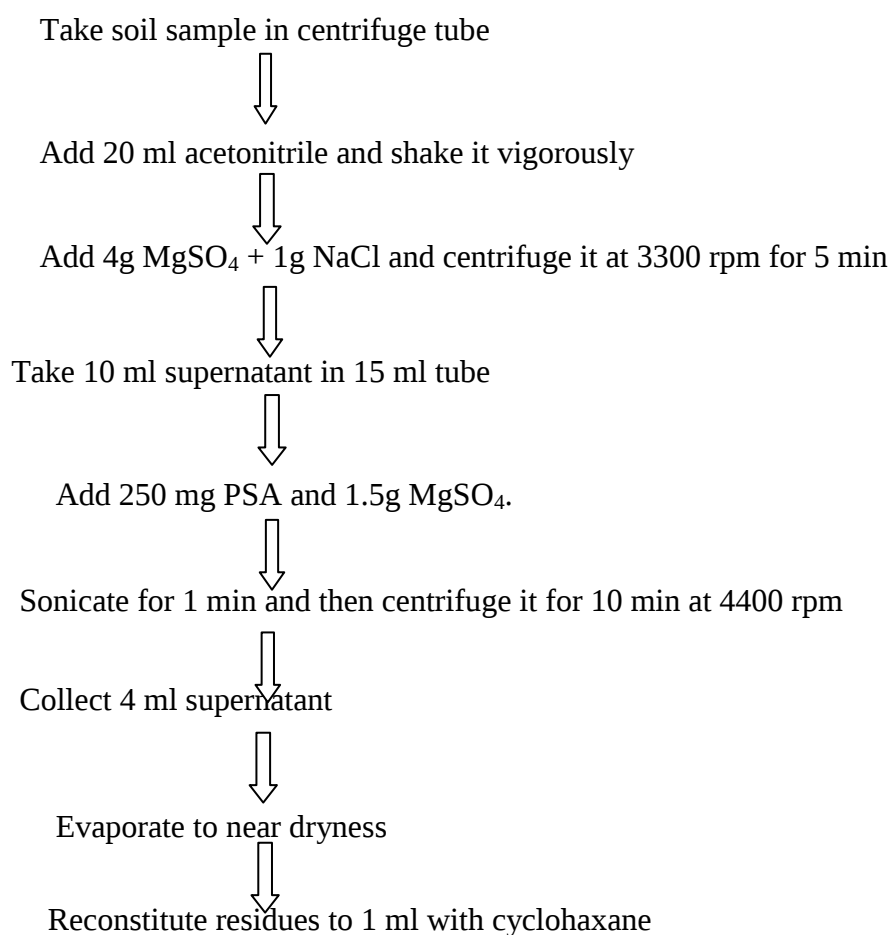
The cation exchange capacity of soil was determined by leaching the soil with 1N ammonium acetate and excess of ammonium acetate was removed from the soil with absolute ethanol. The exchanged ammonium ions corresponding to CEC of soil was then extracted with 1N KCL solution and determined by kjeldahl distillation. Jackson (1973).

3.3.1.3. Fractions of NPK: The following methods were used to determine different forms of NPK Table 8.

Table 8. Methods used for NPK fractionation

Sr. No.	Fractions	Methods	References	
A. Nitrogen fractions				
a)	Exchangeable NH_4^+ -N	2M KCl extractant with MgO powder by macro-kjeldahl method	Hesse (1971)	
b)	Exchangeable Nitrate-N	Distillation with Devarda’s alloy	Hesse (1971)	
B. Phosphorus fractions				
	Inorganic-P fractions	Extractant used	Shaking time	
a)	Saloid-P	1 M NH_4Cl	30 min.	Peterson and Corey (1966)
b)	Aluminium-P	0.5 M NH_4F	1 hr.	
c)	Iron-P	0.1 M NaOH	17 hr.	
d)	Occluded-P	0.1 M NaOH	1 hr.	
e)	Calcium-P	0.25 M H_2SO_4	1 hr.	
f)	Reductant soluble-P	0.3 M Na-citrate	10 min.	
g)	Total inorganic-P	addition values of all inorganic P fractions		
C. Potassium fractions				
1.	Water soluble-K	Using water as extractant (1:5 soil: water ratio)	Jackson (1973)	
2.	Exchangeable-K	1N ammonium acetate extractant	Hanway and Heidel (1952)	
3.	Non-exchangeable K	1N HNO_3 boiling method	Wood and DeTurk (1941)	
4.	Available potassium	addition values of Water soluble+ Exchangeable K fractions	Jackson (1973)	

3.3.1.3. Pesticide residues analysis in soil: It was estimated by QUECHERS methods as described below given by Sharma (2005).



3.3.2 Plant analysis

a) Total nitrogen

The plant samples were digested with conc. H₂SO₄ and the total nitrogen content was determined by Kjeldahl apparatus (Tandon, 1993).

ii) Total phosphorus and potassium

For determination of P, K, Ca, Mg, S 1.0 g plant sample were digested with di-acid mixture ($\text{HNO}_3 + \text{HClO}_4$) with the ratio 9:4 and acid extract was used for determination of P, K, Ca, Mg, S. (Singh *et al.*, 1999).

b) Phosphorus

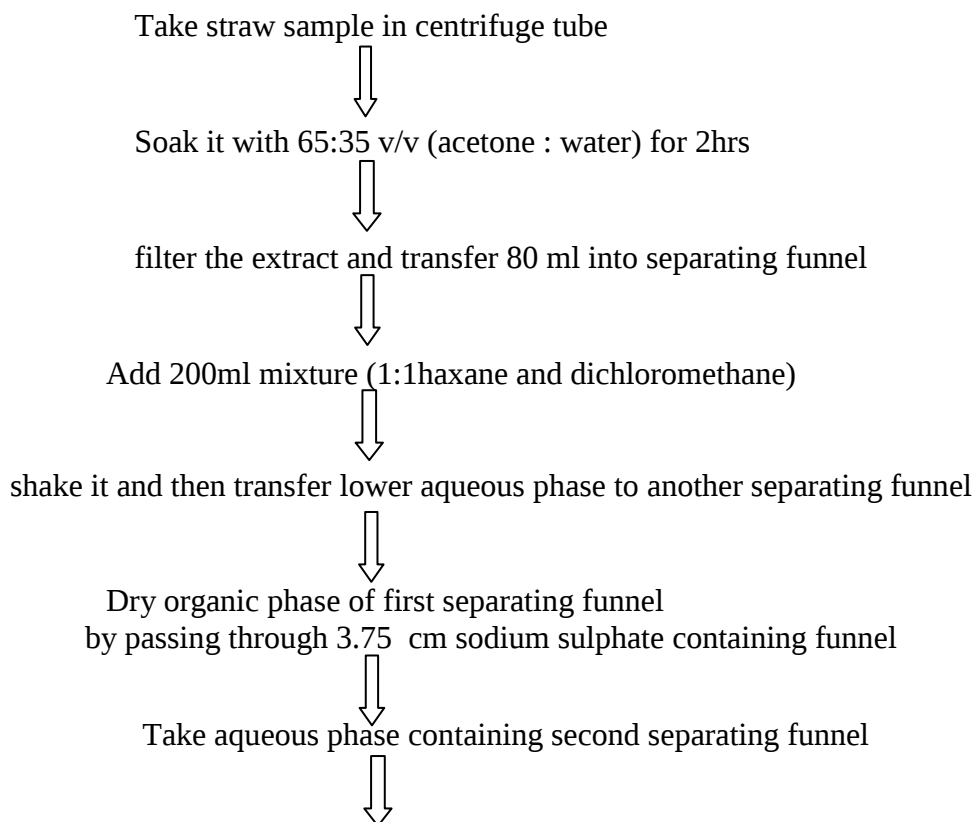
It was determined by using known quantity of di-acid extract as mentioned above and the yellow colour was developed with combined HNO_3 vanadomolybdate reagent. The color intensity was measured using spectrophotometer at 420 nm wavelengths (Chopra and Kanwar, 1978).

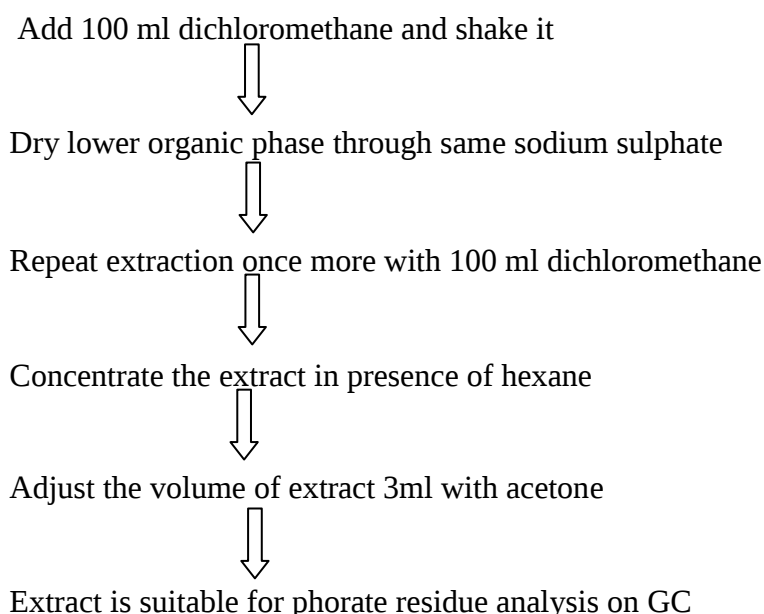
c) Potassium

It was estimated flame photometrically by feeding diluted diacid digested solution diluted 10 times (Piper, 1966).

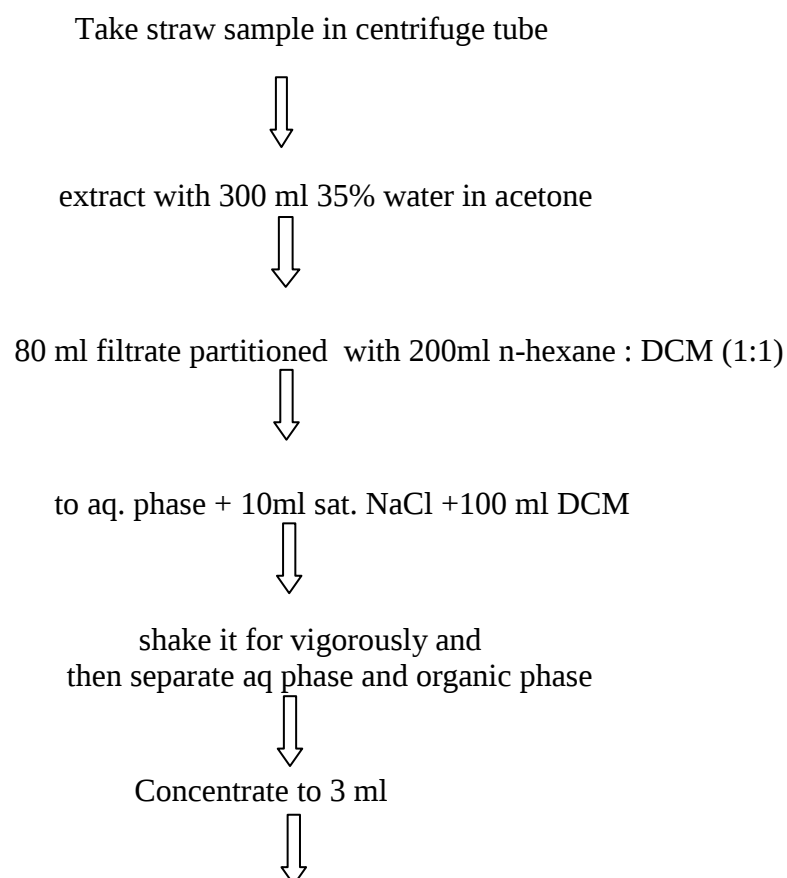
d) Pesticides residues in straw of rice: Phorate was estimated QUECHERS method given by Sharma (2005).

i) Phorate residues analysis in rice straw sample: Phorate was estimated QUECHERS methods given by Sharma (2005). The flow charts of the step involved are as under.





ii) Carbofuron residues analysis in rice straw sample: It was estimated QUECHERS as described by Sharma (2005). The flow sheet of steps involved is as under:



Take 1ml in florisil column cleanup

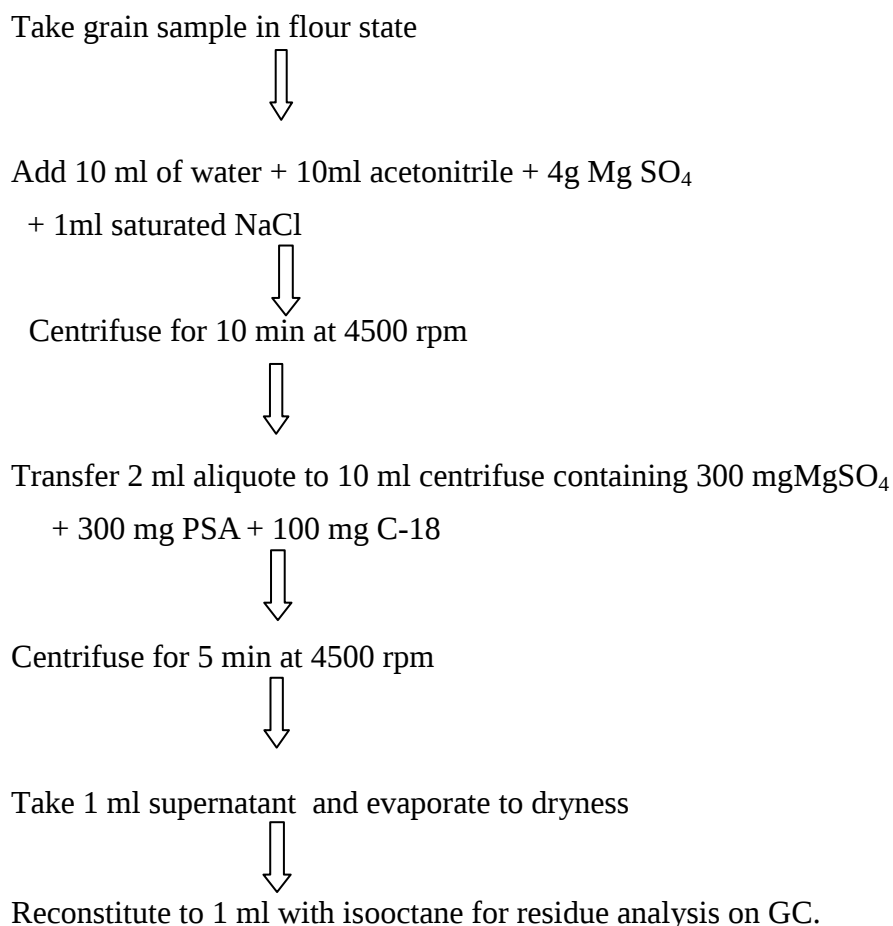


Elution with 50 ml DCM +acetonitrile
+ hexane (50% +1.5 % + 48.5 % v/v)



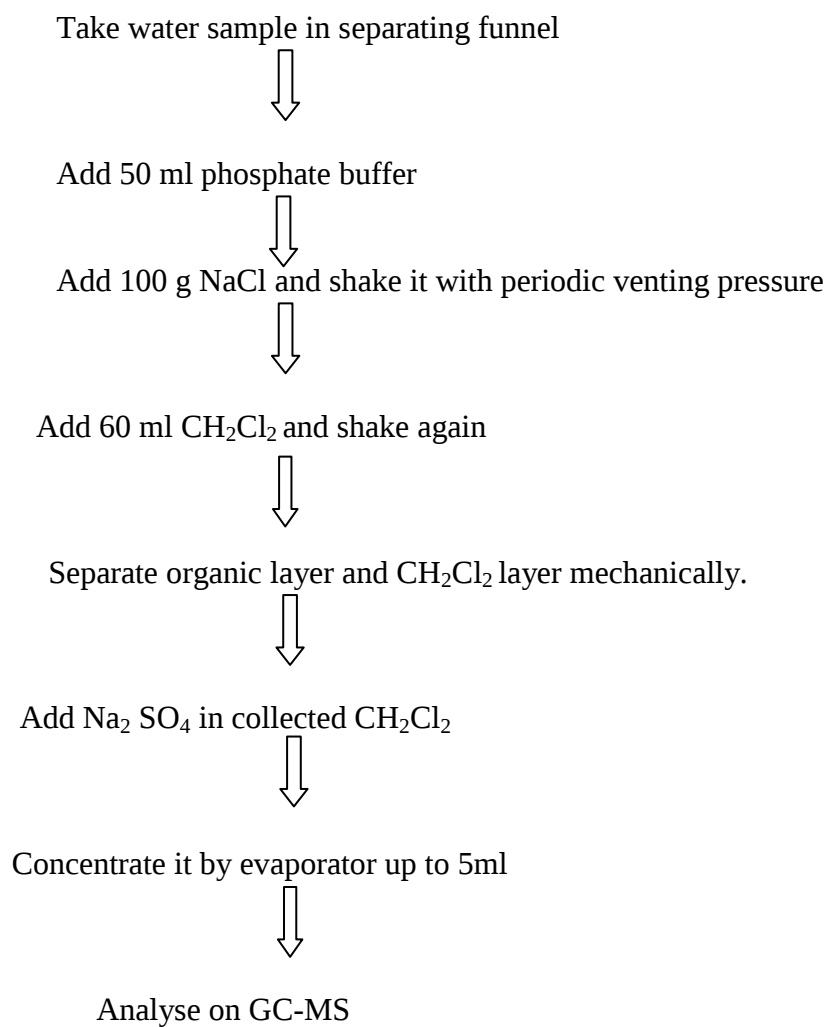
Extract is suitable for Carbofuron residue analysis on GC

iv) Residues analysis in rice grain sample: It was estimated QUECHERS methods as described below given by Sharma (2005).



B. Soil leachate Analysis during rice crop grown in pots

1. **Ammonical Nitrogen** : It was determined by distillation using MgO as prescribed by (Tanadon, 1993)
2. **Nitrate Nitrogen**: It determined by distillation using Devarda,s alloy as prescribed by (Tanadon, 1993)
3. **Potassium** : It determined by using Flame photometer as prescribed by (Tandon, 1993)
4. **Phosphorous**: It determined by using mixture of Ammonium molybdate and potassium antimony tartarate which get reduced by ascorbic acid and form Molybdenum blue colour was developed as prescribed by (Tandon, 1993)
5. **Carbofuron and Phorate residue in water**: It determined by using AOAC method given by Sharma (2005). as follow.



3.3.3 Statistical analysis

The data were statistically analyzed by using the standard procedure given by Panse and Sukhatme (1967).



experiment

Fig 2: General view of pot culture rice at maximum tillering stage



Fig 3: General view of leaching column experiment

CHAPTER II

REVIEW OF LITERATURE

In the present chapter available literature on the topic entitled “movement behaviour of primary nutrients, carbamate and organophosphate based insecticides in different soil matrices”, has been briefly reviewed under suitable headings as follows:-

- 2.1 Physico-chemical characteristics of soils.
- 2.2 Leaching losses of primary nutrients and pesticides from soils.
- 2.3 Effect of pesticides on availability of primary nutrients in soils
- 2.4 Dynamics of primary nutrient fractions in soils.
- 2.5 Pesticides residue content.

2.1 Physico-chemical characteristics of soils

Soils of various places show different characteristics as influenced by their respective climatic condition, slope, vegetation and stage of weathering of soil. These differences in the physico-chemical characteristics of soils, in general can be ascribed to variation in movement behavior of primary nutrient and pesticides in soil. Thus, the various physico-chemical properties of different soils has been briefly reviewed under suitable headings as follows.

2.1.1. Physical properties of soil

2.1.1.1. Mechanical analysis of soil:

Yadav (1988) observed that the sand content of the lateritic soil of Konkan region (M.S.) increased upto depth of 45 cm and decreased below 45 cm soil depth. Datta *et al.*, (1999) found that the clay content in surface and profile soil of higher slopes was lower than that of lower slopes. From these observations, they concluded that the topography of soil affects the clay content of the soil.

Modak (1990) examined the physico-chemical properties of four different soil profile of Konkan region and observed that the sand content in soils varied from 46.48 - 53.52, 21.76 - 32.48, 21.76 - 27.76 and 23.76 - 35.04 percent corresponding to Karjat,

Roha, Repoli and Panvel series of Raigad district, respectively. It was maximum (53.52 percent) in Karjat and minimum 21.76 percent in Roha and Repoli series. As regards the silt content in soil, it ranged from 28.72 - 34.00, 19.04 - 29.76, 27.76 - 31.76 and 21.76 - 22.48 percent for Karjat, Roha, Repoli and Panvel series, respectively. The clay content in these soils varied from 16.48 - 21.76, 46.48 - 51.76, 41.76 - 49.76 and 42.48 - 54.48 percent for Karjat, Roha, Repoli and Panvel series, respectively.

Alexander (1991) examined the physico-chemical properties of different soil profile of Thane districts (Palghar, Shahapur, Dahanu and Wada) and observed that at 0-30 cm depth the sand, silt and clay content were in the order of 44.04, 21.64 and 34.32, for 30-60 cm depth it was in the order of 40.96, 22.00 and 37.04 percent, while at 60-90 depth it gave an order of 38.96, 22.00 and 39.04 percent respectively for Palghar soil Profile. They also observed that at 0-30 cm depth the sand, silt and clay content were in the order of 46.96, 32.00 and 21.04, for 30-60 cm depth it was in the order of 36.60, 28.00 and 35.40 percent, while at 60-90 depth it gave an order of 42.60, 26.00 and 31.40 percent respectively for Shahapur soil Profile. They also observed that at 0-30 cm depth the sand, silt and clay content were in the order of 50.96, 22.00 and 27.04, for 30-60 cm depth it was in the order of 48.96, 22.00 and 29.04 percent, while at 60-90 depth it gave an order of 50.60, 20.00 and 29.40 percent respectively for Dahanu soil Profile. They also observed that at 0-30 cm depth the sand, silt and clay content were in the order of 40.60, 24.00 and 35.40, for 30-60 cm depth it was in the order of 37.32, 25.64 and 37.04 percent, while at 60-90 depth it gave an order of 41.32, 23.28 and 35.40 percent respectively for Wada soil Profile. The result indicates the sand content showed a declining trend with increasing in depth profile. The silt and clay content was found to be increasing at 30-60 cm depth in all soil profile with a decrease at 30-90 cm depth.

Malvade (1993) observed that the clay content of the lateritic soils of Konkan (M.S.) had a wide variation from low as 9.90 percent to as high as 69.70 percent. Further he reported an increase in the clay content with the soil depth. Sharma *et al.*, (2004) reported that the sub-surface horizons of Neogal watershed in North-West Himalayas exhibit higher clay content as compared to surface horizons due to the illuviation process occurring during soil development.

Dhane and Shukla (1995) observed that the clay content of Vertisols, Inceptisols and Entisols of Maharashtra ranged from 29.60 - 55.20, 17.20 - 53.20 and 21.80 -

27.60, respectively. Malewar (1995) observed that the clay content in the Inceptisols and Vertisols of Maharashtra having a cultivation of crops was found in the range of 18.20 - 20.00 and 42.80 - 54.80 percent, respectively. Chinchmalatpure *et al.*, (2000) observed that the silt content varied from 5.00 - 47.80 percent without any specific trend with soil depth in soils of Maharashtra. In general, the silt content of the soils of Maharashtra was reported by Chavan *et al.*, (1980) and Todmal *et al.*, (2008) in the range of 2.45 - 63.27 percent with uneven distribution with soil depth.

Mahajan (2001) observed that the silt content in surface soil was 12.40 - 28.90 percent and in profile soil 8.00 - 23.80 percent in lateritic soils of Konkan (M.S.) region. He also observed a slight increase in the silt content with increasing depth of soil at few locations.

Nayak *et al.*, (2002) examined the particle size distribution in Alfisols (lateritic) of some benchmark soils of West Bengal indicated that a distinct increase in clay content in sub-surface (Bt) horizons. The similar results were also reported by Vaidya (1988).

Patil and Prasad (2004) observed that the clay content ranged from 44.5 - 50.7 percent and increased with depth in soils of Dindori district in Madhya Pradesh. Further, these soils were developed over basalt or partly laterized basalt and hence produced higher amount of clay. Similarly, the illuviation process also affected the vertical distribution of silt and sand contents.

Gabhane *et al.*, (2006) reported that the clay content in soils in Vidarbha region of Maharashtra ranging from 34.4 - 73.4 percent and it increased with depth while the silt content ranged from 12.8 - 40.0 percent and sand content was less than 10.0 percent in soils

Shinde (2006) studied physico-chemical properties of lateritic soil from Ratnagiri and Sindhudurga districts and reported that the sand content was found in the range of 42.68 - 67.00 percent and 40.15 - 51.10 percent at 0-30 cm and 30-60 cm soil depths, respectively. He also found that the sand content was inversely proportional to the soil depth while the clay content at 0-30 cm depth ranged from 23.11 - 44.55 percent and at 30-60 cm depth it varied from 28.72 - 47.00 percent. Further, he observed that the clay content was found to increase from upper surface to lower surface of soil from 33.92 - 40.89 percent.

Patil *et al.*, (2010) reported higher clay content in soils developed on basaltic capping over shell than that developed on basaltic alluvium and sand stone. The silt content of lateritic soils of Konkan (M.S.) region was in the range of 14.20 - 47.00 percent.

Suryavanshi (2010) from his studies on 'Micronutrient status and its relationship with soil properties in soils of Sindhudurga district' observed that the sand content of soil at 0 -15, 15 - 30 and 30 - 45 cm depth varied from 47.80 - 57.83, 44.26 - 56.80 and 42.30 - 54.53 percent respectively with a decreasing trend of sand content with soil depth. The silt content in surface soils of Konkan (M.S.) ranged as 13.41 - 17.11 percent and 11.08 - 19.10 percent in profile soils. He also reported no specific trend of silt content with soil depth.

2.1.1.2. Bulk density (BD) of soil

Patro and Mishra (1985) observed the particle density as 2.60, 2.62, 2.68, 2.66 Mgm^{-3} at respective soil depths of 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm in *Typic haplustult* profile. Datta *et al.*, (1990) found that lowland soils have high particle density than upland soils.

Bharambe *et al.*, (1990) reported the bulk density of soils of Maharashtra in the range of 1.24 - 1.41 Mg m^{-3} at 0-30 cm depth and 1.34 - 1.43 Mg m^{-3} at 30-60 cm depth. A slight increase in bulk density with depth was also observed. The increase in bulk density with depth was attributed to lower organic matter, more compaction and less aggregation in rice soils of Eastern region of Varanasi (Singh and Agrawal, 2005). The bulk density of the soils in Sivagiri micro-watershed of Chittoor district, Andhra Pradesh varied from 1.32 Mg m^{-3} in *Typic Rhodustalfs* to 1.90 Mg m^{-3} in *Aquic Ustorthents* and the values increased with depth. The increase in bulk density with depth was due to compaction of finer particles in deeper layers caused by over head weight of the surface soils. Further, the low bulk density values of surface soils were due to high organic matter content (Thangaswamy *et al.*, 2005). The higher bulk density in soils of Shikohpur watershed of Gurgaon district, Haryana was due to their coarse texture and in some cases the presence of calcium carbonate and low organic carbon content (Sitanggang *et al.*, 2006).

Chavan *et al.*, (1995) revealed that particle density of lateritic soil of Ratnagiri district varied between 2.45 - 2.61 Mg m⁻³ and 2.48 - 2.74 Mg m⁻³ at 0-30 and 30-60 cm depths, respectively. A slight increase in particle density with soil depth was observed.

Gupta *et al.*, (1999) observed that the bulk density ranged from 1.40-1.80 Mg m⁻³ in Inceptisols and 1.40-1.60 Mg m⁻³ in Alfisols of granitic terrain in Jabalpur district of Madhya Pradesh. Singh *et al.* (1999) found that the bulk density varied from 0.83 - 1.22 Mg m⁻³ in the surface soils and increased with depth in soils of Ramganga catchment.

Ramprakash and Rao (2002) stated that the bulk density values of red soils were higher (1.45 - 1.63 Mg m⁻³) than black soils (1.30 - 1.57 Mg m⁻³). Marathe *et al.*, (2003) reported that the bulk density values varied from 1.46 to 1.74 Mg m⁻³ and the bulk density was also increased with increasing depth in mandarin orchards of Nagpur. The bulk density in the soils of Maul Khad catchment of Himachal Pradesh varied from 1.38 to 1.62 Mg m⁻³ in surface and 1.35 to 1.72 Mg m⁻³ in sub-surface horizons. The bulk density tends to increase with depth. The variation in bulk density was attributed to variation in organic matter, texture *etc.* (Sharma and Anil Kumar, 2003).

Kuchanwar *et al.*, (2005) reported that the bulk density of soils of Maharashtra ranged from 1.15 - 1.27 Mg m⁻³. Shinde (2006) observed that bulk density of lateritic soil of Konkan (M.S.) at surface and profile varied from 0.99 - 1.47 and 0.98 - 1.38 Mg m⁻³ respectively. Further no specific trend of bulk density with soil depth was found (Shinde, 2006). However, it was noted that a slight increase in bulk density with depth by Mahajan (2001).

Sankpal (2008) reported the particle density of lateritic soil in the range of 2.21 - 2.72 Mg m⁻³. He also observed no specific pattern of particle density with soil depth. Mahajan (2001) observed that the particle density of surface soil ranged from 2.62 - 2.83 Mg m⁻³, while the soil profiles showed particle density in the range of 2.21- 2.88 Mg m⁻³. He found that the higher particle density of lateritic soils was due to the presence of kaolinite, haematite and fine grained mica in this soil. He also noticed that there was no appreciable change in particle density with soil depth.

Patil *et al.*, (2008) observed higher values of bulk density of surface soil 1.83 Mg m⁻³ and lower values for the profile soil 1.33 Mg m⁻³. However, at certain places he found higher values of bulk density for profile soils. The bulk density in the Entisols

and Inceptisols of Shahibi basin in Haryana and Delhi varied from 1.48-1.87 Mg m⁻³ and 1.50-1.69 Mg m⁻³, respectively. The higher bulk density values could be due to their coarse texture and low organic matter content (Swarnam *et al.*, 2004).

Sankpal (2008) revealed from his study that bulk density of surface soil varied from 1.09 - 1.48 Mg m⁻³ and in profile soil it ranged between 1.39 - 1.52 Mg m⁻³. He found no specific trend of bulk density with soil depth.

Suryavanshi (2010) found that particle density of lateritic soil of Sindhudurga district ranged from 2.34 - 2.56 Mg m⁻³ with a mean of 2.45 Mg m⁻³. He further reported that there was no specific trend of particle density with soil depth. Rao *et al.*, (2010) reported the lower bulk density of surface soil than soil profile. It may be due to elevated cultivation, organic matter and biotic activities in the surface soil.

2.1.2. Chemical properties of soils:

2.1.2.1. pH and electrical conductivity:

Dabke (1987) reported electrical conductivity of soils of Konkan (M.S.) to be in the range 0.01 - 0.02 dS m⁻¹, without any specific trend of distribution with soil depth. On the other hand, Shah (1992) reported a decrease in electrical conductivity with soil depth.

Joshi and Kadrekar (1988) reported that the soil pH ranged from slightly acidic to slightly alkaline in Very high Rainfall Non lateritic Soil of Konkan region (M.S.) as against moderately acidic to strongly acidic in Very high Rainfall Lateritic Soil of Konkan region (M.S.). Due to relatively low rainfall coupled with shallow saline water table and impeded drainage, the average value of EC of the soils in VRN zone was significantly higher (25 dS m⁻¹) than of the soils in VRL zone (11.9 dS m⁻¹).

Mali (1989) analyzed the soils from Karjat, Roha, Repoli and Panvel and reported the average electrical conductivity was 0.39, 0.29, 0.28 and 0.28 mmhos cm⁻¹ for Karjat, Roha, Repoli and Panvel soils, respectively.

Modak (1990) examined the physico-chemical properties of different soil profile of Konkan region (Roha, Karjat, Repoli and Panvel) and observed that the pH of soils varied from 6.9 - 7.3, 6.9 - 7.3, 7.0-7.5 and 7.9 - 7.9 for Karjat, Roha, Repoli and Panvel series, respectively. Further, they observed that the electrical conductivity in soils varied from 0.243 - 0.315, 0.306 - 0.351, 0.252 - 0.315 and 16.20 - 16.74 dS m⁻¹

for to Karjat, Roha, Repoli and Panvel series, respectively. The higher electrical conductivity value of Panvel soil series than other soil series as the soils of this series were highly saline containing more soluble salts. These results were in conformity with the results obtained by Joshi (1985).

Alexander (1991) studied the characterization of physico-chemical properties in benchmark soils of Palghar, Shahapur, Dahanu and Wada of Thane districts. He further observed that the electrical conductivity values in all the soil profiles ranged between 0.070 - 0.223 dSm⁻¹ whereas cause of low electrical conductivity was might be due to leaching of soluble salt from soil profile due to heavy precipitation in this region. The declining trend of electrical conductivity was also reported as depth increased.

Alexander (1991) studied the characterization of physico-chemical properties in benchmark soils of Palghar, Shahapur, Dahanu and Wada of Thane districts and analyzed the soil profile samples of benchmark soil series. They observed that the pH values of surface soil indicated comparatively lower value in all the soil profiles. The pH value of soil profile of this region ranged between 6.8 - 7.3. It showed marked increase with increase in soil depth in almost all soil profile of benchmark soil series. The increasing trend in pH values at lower depths in all the profiles may be attributed to leaching of bases from surface layers to the sub-surface layers.

Dongale and Kadrekar (1992) studied the lateritic soils of Konkan (M.S.) and observed that the pH values varied from 5.10 - 7.20. Dongale (1993) from his study on the soils of Ratnagiri district found that the soils were acidic in reaction and pH values ranged from 5.70 - 6.90. No specific trend of pH was found with soil depth.

Walia and Rao (1996) noticed that the electrical conductivity of soils in Bundelkhand watershed of Uttar Pradesh was low (less than 0.1 dS m⁻¹) suggesting very low amount of soluble salts. Chinchmalatpure *et al.*, (1998) concluded that the low electrical conductivity (0.08 - 0.4 dS m⁻¹) in soils of Trans Yamuna plains indicated the low amount of soluble salts. The electrical conductivity of Vertisols and Inceptisols developed from different parent materials were normal with very low (< 1 dS m⁻¹) salt content.

Powar and Mehta (1999) reported that soils under study were mostly silty loam to sandy loam. These were slightly alkaline with electrical conductivity varying from 5.40 - 17.20 dS m⁻¹.

Das *et al.*, (2000) noted the pH of red lateritic soil of West Bengal was in between 5.02 - 5.80 which showed the acidic nature of the soil. They also noted that the pH increased with soil depth. Similar observations for the lateritic soils of Maharashtra were also reported by Todmal *et al.*, (2008) and Verma *et al.*, (2005) and also observed similar pattern with soil depth. Higher values of pH were associated with presence of high degree of base saturation in the soil and vice versa (Shrinivas *et al.*, 2011) soils of Ratnagiri district were found to be more acidic with pH values between 4.50 and 5.20.

Sarkar and Sahoo (2000) and Patil *et al.*, (2008) found that the pH value increased with depth as soil alkalinity increases with depth due to deposition of basic salts by irrigation and eluviations. Chinchmalatpure *et al.*, (2000) found that the organic carbon content of basaltic land form was higher than that of sand stone land form.

Padole and Mahajan (2003) and Waghmare *et al.*, (2008), found lower electrical conductivity for properly managed soils due to leaching of salts from surface to subsurface caused by downward movement of water.

According to Pillai and Natarajan (2004) the electrical conductivity of the soils of Garakahalli watershed ranged from 0.02 - 0.20 dS m⁻¹ indicating non-saline nature of the soil. However, these soils did not show any relationship with depth. This may be due to the undulating nature of the terrain coupled with free drainage conditions, which favoured the removal of released bases by the percolating and drainage water. Swarnam *et al.*, (2004) observed that the Inceptisols and Entisols of Shahibi basin in Haryana and Delhi were non-saline with electrolyte concentration ranging from 0.18 - 0.95 dS m⁻¹.

Sawant (2004) observed that the pH of lateritic soils ranged between 4.78 - 5.46 while Pereira *et al.*, (1986) reported that pH values of soils of Ratnagiri district on lower slopes was found in the range between 5.40 - 6.30 with an average value of 5.90 while on higher slopes it ranged from 5.00 - 6.10.

Thangaswamy *et al.*, (2005) found that the pH values of upland soils were comparatively lower than that of lowland soils. This may be due to surface runoff of upland soils. The pH value of soil was mainly decided by three factors namely the parent material, rainfall and topography.

According to Sitanggang *et al.*, (2006) the pH varied from slightly acidic to alkaline with a range of 6.11- 8.57 in the soils of Shikohpur watershed of Gurgaon district, Haryana. The increase in soil reaction down the slope could be due to leaching of bases from higher topography and getting accumulated lower elevations and also high concentration of CaCO₃ in the lower areas. Soil pH varied from 7.1 - 8.6 and the

relatively high pH of the soils might be due to the presence of high degree of base saturation in soils of Tonk district of Rajasthan (Meena *et al.*, 2006).

Todmal *et al.*, (2008) also observed an increasing trend of electrical conductivity with soil depth. It may be attributed to poor drainage of water at higher depths. Chavan *et al.*, (1980) studied the electrical conductivity of soils of Ratnagiri district and found that it varied from 0.01 - 0.15 dS m⁻¹.

Somasundaram *et al.*, (2009) studied the soil properties and found a higher value of electrical conductivity. It may be due to the inflow of soluble salts through irrigation water.

Suryavanshi (2010) observed that the pH values of lateritic soils of Konkan (M.S.) region ranged between 4.33 - 6.44, 4.47 - 6.97 for 0-30 and 30-60 cm depth, respectively. Further, Patil (1981) also reported similar range of pH for lateritic soils of Konkan region (M.S.). However, he also observed no specific trend of pH with soil depth.

2.1.2.2. Organic carbon:

Mali (1989) analyzed the soils from Karjat, Roha, Repoli and Panvel and reported the mean organic carbon content in Karjat soils was (0.46 percent), Roha (0.34 percent), Repoli (0.29 percent) and Panvel (0.25 percent).

Modak (1990) examined the physico-chemical properties of different soil profile of Konkan region (Roha, Karjat, Repoli and Panvel) and observed that the organic carbon content of these four soil varied from 0.30 - 0.58, 0.33 - 0.39 , 0.24 - 0.33 and 0.27 - 0.33 per cent for Karjat, Roha, Repoli and Panvel series respectively. Low organic carbon content of soils of this region may be due to intensive cropping without adding FYM or compost.

Alexander (1991) examined the physicochemical properties of different soil profile (Palghar, Shahapur, Dahanu and Wada) from Thane Districts of Konkan region. The organic carbon content of these regions soils ranged between 0.20 - 0.53 percent. Further he indicated that as the depth increased the organic carbon content in soil showed a declining trend in Palghar, Shahapur and Dahanu soil series, while the organic carbon content increased with depth at 30-60 cm and decreased at 60-90 cm depth. The decrease in the organic carbon content with increasing depth of soil profile was also expected as the recycling of organic waste and its decomposition rate is more

in the surface layer than the sub-surface layers. All the profiles of benchmark soil series were found to be low in organic content. Similar results were quoted by Yadav (1988).

Sharma *et al.*, (1992) observed that the organic carbon content was medium in surface horizons and low in sub-surface horizons of Inceptisols in North-West India. The organic carbon content in the soils of upper slope varied from 0.90 - 2.80 g kg⁻¹ whereas in the soils of lower slope, it varied from 0.50 - 5.00 g kg⁻¹ (Sarkar *et al.*, 2001).

According to Suresh Kumar *et al.*, (2001) the organic carbon was low (0.42 - 0.50 percent) in soils of residual and denudational hills of Dehradun while the soils of moderately buried pediments and valley fills had medium organic carbon content (0.08 - 0.97 percent).

Sarkar *et al.*, (2002) reported that the organic carbon content in the surface soils of Loktak catchment area in Manipur ranged from 24.7 - 45.4 g kg⁻¹ and decreased with depth. The organic carbon in surface horizons of banana growing soils in Wardha district of Maharashtra was (5.5 - 8.7 g kg⁻¹) and it decreased in sub-surface soils to a minimum of 1.4 g kg⁻¹ (Kadao *et al.*, 2003).

According to Singh and Agrawal (2003) the organic carbon content was low (1.0 - 5.6 g kg⁻¹) in Entisols and Inceptisols of Chandauli district, Uttar Pradesh due to the existing rice-wheat cropping system and prevailing semi-arid environment. The organic carbon in soils of uplands showed a regular decrease with depth while the soils in inter-hill valleys exhibited an irregular trend with depth (Bhaskar *et al.*, 2004a).

The organic carbon content in soils of Chandragiri mandal of Chittoor district, Andhra Pradesh varied from 0.6 - 6.3 g kg⁻¹ (plains), 0.8 - 4.1 g kg⁻¹ (uplands) and 3.7 - 6.6 g kg⁻¹ (Hill slope). Irrespective of landforms, the organic carbon decreased with depth (Basava Raju *et al.*, 2005). The organic carbon content invariably high in surface horizons and exhibited a declining trend with depth in forest soils as compared to cultivated soils (Sanjeev *et al.*, 2005). The organic carbon content decreased with the depth in soils of Sivgiri micro-watershed in Chittoor district of Andhra Pradesh. This could be due to the addition of plant residues and farm yard manure to surface horizons than in the lower horizons (Thangaswamy *et al.*, 2005).

Sankpal (2008) reported that the organic carbon in the surface and profile soils showed variation between 3.00 - 18.90 g kg⁻¹. It was observed that a decreasing trend of

organic carbon content with the soil depth. Sarkar *et al.*, (2002) also reported a decreasing trend of organic carbon with soil depth. Organic carbon content in soil was an important parameter of the soil and was significantly responsible for the fertility and productivity of the soil (Bandopadhyay *et al.*, 2008).

Waghmare *et al.*, (2008) opined that the variation of organic carbon content in the soil was attributed to high temperature responsible for hastening the rate of oxidation as well as addition of organic matter and crop residues in the soil. Shrinivas *et al.*, (2011) related the low values of organic carbon content in the soil with higher rate of oxidation in the soil at higher temperature and good aeration.

2.1.2.3. Cation exchange capacity:

Mali (1989) analyzed the soils from Karjat, Roha, Repoli and Panvel and reported the average cation exchange capacity in Karjat soils was (40.40 meq. 100 g⁻¹), Roha (44.04 meq. 100 g⁻¹), Repoli (43.60 meq.100 g⁻¹) and Panvel (44.70 meq. 100 g⁻¹)

Modak (1990) examined the physico-chemical properties of different soil profiles of Konkan region (Roha, Karjat, Repoli and Panvel). They observed that the cation exchange capacity of these four soils varied from Karjat 40 - 40.8, Roha 42.70 - 43.9, Repoli 42.90 - 43.90 and Panvel series 44.85 - 44.90 meq.100 g⁻¹, respectively. The cation exchange capacity value of Panvel, Roha and Karjat soil series than Repoli soil series was because the soils of these series were high clay containing texture.

Alexander (1991) examined the physico-chemical properties of different soil profile of Thane districts (Palghar, Shahapur, Dahanu and Wada). The results revealed that the cation exchange capacity of the soil profile samples at different depths varied between 30.82 - 49.80 meq.100 g⁻¹ of soil. The cation exchange capacity of soil profile did not show any specific trend with soil depth.

Gupta *et al.*, (1999) observed that the cation exchange capacity in soils of granitic terrain in Jabalpur district of Madhya Pradesh varied from 14.70 - 55.40 Cmol (P⁺) kg⁻¹ soil which was mostly related to the clay content of soils. Cation exchange capacity of the soils of lower outlier in Chhotanagpur plateau varied from 2.00 - 18.00 Cmol (P⁺) kg⁻¹ soil (Sarkar *et al.*, 2001).

Suresh Kumar *et al.*, (2001) found that the cation exchange capacity of soils in residual hills, denudational hills and pediments was low (11.70 - 16.37 Cmol (P⁺) kg⁻¹soil) whereas the soils of shallow and moderately buried pediments and valley fills had

moderately high cation exchange capacity (15.10 - 28.20 Cmol (P⁺) kg⁻¹soil). The cation exchange capacity of Entisols in Etawah district of Uttar Pradesh was low and varying from 3.20 - 10.50 Cmol (P⁺) kg⁻¹ soil which might be due to the presence of low cation exchange capacity bearing minerals while the cation exchange capacity of Inceptisols was medium (10.00 - 19.00 Cmol (p⁺) kg⁻¹ soil) because of comparatively higher clay content (Verma *et al.*, 2001). The cation exchange capacity of the Maul Khad catchment soils in Himachal Pradesh varied from 4.4 - 14.8 Cmol (P⁺) kg⁻¹ soil and was dependent on clay and organic matter. The clay content was significantly and positively correlated with cation exchange capacity (Sharma and Anil Kumar, 2003).

Swarnam *et al.*, (2004) stated that the cation exchange capacity of the soils of Shahibi basin in Haryana and Delhi varied from 3.20 - 10.20 Cmol (P⁺) kg⁻¹soil and decreased with depth. Low cation exchange capacity of these soils could be attributed to low content of clay and organic carbon.

Sharma *et al.*, (2004a) stated that the cation exchange capacity in the soils of Neogal watershed in North-West Himalayas ranged from 4.9 - 14.3 Cmol (P⁺) kg⁻¹ soil. The difference in cation exchange capacity between the soils was due to the varied type /content of soil colloids and soil pH values. The cation exchange capacity of the Garkahalli watershed soils was found to be low to medium. Maximum cation exchange capacity was observed in the horizons where illuviation of clay from surface to sub-surface horizon had taken place (Pillai and Natarajan, 2004).

Cation exchange capacity of the soils in Dindori district of Madhya Pradesh with smectitic mineralogy was higher (72.0 Cmol (P⁺) kg⁻¹) as compared to the soils with mixed mineralogy (28.9 Cmol (P⁺) kg⁻¹) (Patil and Jagdish Prasad, 2004). The cation exchange capacity values were higher in horizons containing high clay and/or high organic carbon content. Low values of cation exchange capacity (9.0 - 11.5 Cmol (P⁺) kg⁻¹) may be ascribed to the predominance of low cation exchange capacity minerals, especially illite, in outer Himalayas (Sanjeev *et al.*, 2005). The cation exchange capacity of the soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh ranged from 1.50 - 45.14 Cmol (P⁺) kg⁻¹soil which corresponds to their clay content in the respective horizons (Thangaswamy *et al.*, 2005).

Gabhane *et al.*, (2006) reported that the cation exchange capacity of soils varied from 51.16 - 62.98 Cmol (P⁺) kg⁻¹and the soils which had lower amount of clay

content had lowest CEC values in a micro - watershed of Vidharbha region in Maharashtra

Balpande *et al.*, (2007) reported that the cation exchange capacity varied from 23.00- 59.00 Cmol (P⁺) kg⁻¹ soil with a tendency to decrease with depth but it was found closely associated with clay and clay plus organic carbon in soils of Nasik district of Maharashtra.

2.1.2.4. Available nitrogen and its inorganic fractions:

Dongale (1989) found the available nitrogen content in the lateritic soils of Konkan (M.S.) in the range of 185.00 - 674.00 kg ha⁻¹. He also observed that the nitrogen content of Sindhudurg district was comparatively less than that of Ratnagiri district.

Mali (1989) analyzed the soils from Karjat, Roha, Repoli and Panvel and reported the mean available nitrogen content in Karjat soils was (130.94 ppm), Roha (97.11 ppm), Repoli (96.38 ppm) and Panvel (112.44 ppm).

Modak (1990) examined the physicochemical properties of different soil profile of Konkan region (Roha, Karjat, Repoli and Panvel). They observed that the available nitrogen content of these four soils varied from 70.30 - 166.58, 94.33 - 101.39, 79.24 - 108.33 and 129.7 - 152.33 ppm for Karjat Roha, Repoli and Panvel series respectively.

Alexander (1991) examined the physico-chemical properties of different soil profiles of Thane districts from Konkan region (Palghar, Shahapur, Dahanu and Wada). The results revealed that the available nitrogen of the soil profile samples at different depths varied from 68.46 - 106 ppm. The available nitrogen showed a gradual reduction with increase in soil depth. Similar results were quoted by Yadav (1988).

Chavan *et al.*, (1995) found that the nitrogen content in the lateritic soils of Konkan (M.S.) was in the range of 253.10 - 260.10 and 153.10 - 161.60 kg ha⁻¹ at 0-30 and 30-60 cm depth, respectively. They found a decreasing trend of nitrogen content with soil depth.

Santhy *et al.*, (1998) studied the N fraction in *Vertic Ustropept* soil. They reported that content of exchangeable NO₃-N and exchangeable NH₄-N in soil was 3.5 and 3.7 ppm respectively.

Shinde (2006) reported that the depthwise nitrogen content in the Lateritic soils of Konkan (M.S.) ranged from 282.24 - 627.00 and 263.28 - 577.02 kg ha⁻¹ at 0-30 and

30-60 cm depth, respectively. He also reported a declining trend of nitrogen content with soil depth and increasing trend with slope of soil.

Gaidhani (2008) reported that available nitrogen content of Lateritic soil in Konkan varied from 227.88 - 298.96 kg ha⁻¹ from his study on integrated nutrient management in rice crop.

Sankpal (2008) observed that the range of available nitrogen in the Lateritic soils of Konkan (M.S.) varied from 149.94 - 482.20 kg ha⁻¹. Further he also reported a decline in trend of nitrogen content with soil depth. However, Vaidya (1988) observed no specific trend.

Rajeswar *et al.*, (2009) and Prasunarani *et al.*, (1992) from their studies reported that the available nitrogen was found to be maximum at the surface horizons. However, it decreased with soil depths which might be due to accumulation of plant residues, debris and rhizosphere. Talukdar *et al.*, (2009) opined that the higher values of nitrogen content in the soil might be due to high content of organic carbon which on mineralization released higher nitrogen.

Suryavanshi (2010) reported that available nitrogen content showed declining trend with soil depth, the respective values found was in the range of 338.94 - 527.62 kg ha⁻¹.

2.1.2.5 Available phosphorous and its inorganic fractions:

Deshmukh *et al.*, (1982) observed that the available phosphorous in the surface soils of Konkan (M.S.) was in the range of 5.01 - 26.14 ppm. The top layers were found richer than the subsurface layers of the soil.

Joshi (1985) observed that in VRN zone of Konkan region, the available phosphate content varies from 8.80 - 399.60 kg ha⁻¹. He also reported that in VRL zone of Konkan region the available phosphate content varies from 3.50 - 150.90 kg ha⁻¹ and the available potash content varies from 111 - 2775 kg ha⁻¹.

Mali (1989) analyzed the soils from Karjat, Roha, Repoli and Panvel and reported the average available phosphorous content in Karjat soils was (32.82 ppm), Roha (9.55 ppm), Repoli (11.01 ppm) and Panvel (26.41 ppm).

Modak (1990) examined the physico-chemical properties of different soil profile of Konkan region (Roha, Karjat, Repoli and Panvel) and observed that the available phosphorous content of these four soil ranged between 16.30 - 78.58, 7.33 - 14.39, 7.24 - 14.33 and 43.7 - 55.33 ppm for Karjat, Roha, Repoli and Panvel series

respectively. Deficient to low status of available P_2O_5 was reported by Parab (1990) in Lateritic soils of Maharashtra.

Alexander (1991) studied physico-chemical properties of different soil profile of Konkan region Thane districts (Palghar, Shahapur, Dahanu and Wada). The available phosphorous of these region soil at different depth ranged between 4.19 - 12.20 ppm. The available phosphorous showed a decline in trend as the depth increased in Palghar and Dahanu, while in case of Shahapur soil series the available phosphorus increased with increase in soil depth. While there were no differences in its content at different soil depths in Wada soil series.

Khadtar *et al.*, (1991) studied the phosphorous fractions in rice growing pot of South Konkan Coastal zone of Maharashtra in Lateritic soil. They reported that inorganic P fractions were ranged between saloid-P (0.64 - 2.88 ppm), Al-P (35 - 137 ppm), Fe-P (74 - 209 ppm), Ca-P (8 - 21 ppm), occluded-P (25 - 77 ppm) and Brays-P (1.5 - 14.4 ppm).

According to Prasunarani *et al.*, (1992) the low content of available P_2O_5 in lateritic soils might be due to low native phosphorous content and fixation of released phosphorous by clay minerals and oxides of Fe and Al.

Raghupati and Bhargava (1997) reported the available phosphorous in the Lateritic soils of Ratnagiri district in the range of 10.40 - 15.60 kg ha⁻¹. They categorized 30 percent of the soils as 'very low' and 16 percent as 'low' in available phosphorous content.

Sahu and Mishra (1997) reported that available phosphorus content ranged between 12.76 -14.00 kg ha⁻¹. The data on the available P status in the soils of Karnataka showed that about 83 percent of the soils are low in P and 17 percent under medium category.

Talashilkar and Chavan (1997) investigation carried out the influence of soil reaction on the P fraction of Dapoli, Konkan region of Maharashtra. The result indicated that mean values of Ca-P, saloid-P and occluded-P varied in lateritic soil 13.4, 3.0 and 40.7 ppm varied from very strongly acidic soil group respectively.

Santhy *et al.*, 1998 studied the P fraction in *Vertic Ustrolept* of Tamilnadu. They reported that the content of saloid-P, Al-P, Fe-P, Ca-P and Olsen P as 1.0, 29.2, 26.0, 169, 2.3 ppm respectively.

Sharma and Bali (2000) observed that the declining trend of phosphorous was due to higher fixation of it with depth. Thangaswamy *et al.*, (2005) stated that the

higher content of phosphorous in soil was due to confinement of crop cultivation to surface layer and supplementation of the depleted P_2O_5 through fertilizers.

Singh *et al.*, (2003) studied the phosphorous fraction and their relationships to weathering and indices in Vertisol of Udaipur Rajasthan. They reported that Calcic Gneiss complex derived Vertisol soil were higher in Ca-P (84.1 - 88.9 ppm) followed by basaltic alluvia derived soil (66.0 - 68.4ppm) and Basalt derived soil (39.4 - 47.4ppm). They reported that content of inorganic fraction in Calcic Gneiss complex derived Vertisol soil were in the range of Al-P (15.5 - 20.6 ppm), Fe-P (12.6 - 17.6 ppm), occluded-P (5.1 - 10.6 ppm) while basaltic alluvia derived soil content of inorganic fraction in the range of Al-P (21.6 - 27.6 ppm), Fe-P (16.6 - 17.6 ppm), occluded-P (8.1 - 12.6 ppm) and content of inorganic fraction in Basalt derived soil the ranged between Al-P (24.6 - 28.6 ppm), Fe-P (21.6 - 24.6 ppm), occluded-P (13.1 - .6 ppm).

Tamboli and Daftardar (2003) studied the Inorganic phosphorus fractions in some Vertisol Rahuri (Nimone series) and Alfisol (Wakawali series) soils of Maharashtra. They reported that Among the different P fractions, (Nimone series) contains saloid-P (10.3 ppm), Al-P (22.5 ppm), Fe-P (16.95 ppm), reductant soluble-P (47.7 ppm), and Ca-P ppm (374.5 ppm) while (Wakawali series) contains saloid-P (8.46 ppm), Al-P (20.58 ppm), Fe-P (33.37 ppm), reductant soluble-P (63.45 ppm), and Ca-P (11.07 ppm).

Laxminarayana (2007) studies the distribution of inorganic P fraction and critical limits of available P in rice soil of Mizoram. He resulted that constituent of total P in these soil followed the order RS-P (34 percent) > Fe-P (15.8 percent) > Ca-P (12.0 percent) > Al-P (19.6 percent) > saloid-P (2.46 percent). While the total P in the soils ranged from 132.3 - 365.8 ppm.

Mujumdar *et al.*, (2007) studied the soil-P pool in *Typic Hapludalf* (Alfisol) of Meghalaya. They reported that among the inorganic P fractions viz. saloid-P, Al-P, Fe-P, Ca-P, occluded-P and reductant soluble-P of ranged between 1.7, 47.0, 45.0, 3.3, 55.0 and 78.0 ppm respectively.

Setia and Sharma (2007) studied the dynamic of inorganic phosphorous form. The relative abundance of P fraction in sandy loam *Typic Haplustept* was in the order of saloid P < Fe-P < Al-P < Ca-P i.e. saloid-P, Al-P, Fe-P and Ca-P was 5.7, 39.0, 220 and 458 mgkg⁻¹ respectively.

Singh and Sharma (2007) studied the fractionation of various inorganic forms of P in soils of Punjab revealed that on an average, the content of saloid-P, Al-P, Fe-P and Ca-P were 2.9, 20.0, 5.3 and 243 ppm respectively.

Yadav *et al.*, (2007) computed the inorganic fraction of soil. He revealed that the range of available phosphorous 6.25 - 15.18 ppm, saloid-P 2 - 5.60 ppm, Fe-P 8.40 - 22.5 ppm, Ca-P 201 - 360 ppm. The saloid-P, Al-P, Fe-P and Ca-P constituted 0.31-4.91, 2.73 - 8.24, 1.38 - 5.49 and 39.20 - 61.98 percent of the total inorganic P fractions respectively.

Ram and Mukhopadhyay (2008) studied the inorganic phosphorus fractions in some acid soils under *terai* situations of West Bengal. They reported that among the different P fractions, the saloid bound P ranged from 0.88 - 3.50 mg kg⁻¹, Al-P ranged from 11 - 45 mg kg⁻¹, Fe-P ranged from 23.3 - 150.0 mg kg⁻¹, RS-P ranged from 45.3 - 146.6 mg kg⁻¹ and Ca-P ranged from 5.33 - 42.0 mg kg⁻¹, respectively. It has been observed that the saloid bound P is the least among the fractions.

Sankpal (2008) reported the available phosphorous in the range of 0.30 - 38.75 kg ha⁻¹ including surface and profile soils in lateritic soils of Konkan (M.S.). They also reported a declining trend of available phosphorous with soil depth.

Talukdar *et al.*, (2009) found that available phosphorous content is related with the organic carbon content in the soil while Tiwari *et al.*, (1987) observed that the available phosphorous was more in spring due to higher microbial activity in soil in this season releasing the phosphorous with faster rate.

Dasog *et al.*, (2010) studied the inorganic phosphorous in a lowland acid soil of coastal agroecosystem of Karnataka. He recorded the inorganic fraction in coastal soil as available P (7.4 kg ha⁻¹), saloid-P (2.4 ppm), Al-P (50.1 ppm), Fe-P (95.2 ppm), reductant soluble-P (86.7 ppm), occluded-P (13.6 ppm) and Ca-P (14.1 ppm).

Lungmuana (2012) studied distribution of different forms of phosphorus in surface soils of rice growing areas of Red and Laterite Zone of West Bengal. They reported that content of saloid-P, Al-P, Fe-P, RS-P, Ca-P and total inorganic-P ranged between 1.03 - 3.00 ppm, 11.0 - 45.22 ppm, 1.03 - 8.33 ppm, 46 - 118 ppm, 5.33 - 34.67 ppm and 94 - 379 ppm respectively.

Niranjana *et al.*, (2012) studied the vertical distribution of phosphorous fractions in profile of Vertisol and Inceptisol of different agroclimatic zones of Karnataka. They reported that Ca-P was observed with range from 70.57 - 350.84 ppm. And its content decreased with depth. Residual - P distribution with depth did not

follow any definite trend and its value ranging from 38.80 - 84.56 ppm. Occluded P content varied from 21.32 - 135.29 ppm. The saloid-P content ranged from 6.71 - 33.82 ppm i.e, on an average 3.14 percent of total P. Its content decreased with depth. The distribution of Fe-P did not follow any definite pattern with depth. Its content ranged from 8.09 - 238.97 ppm. The average relative abundance of different fractions was in the order of Ca-P (139.57ppm) > Fe-P (89.01 ppm) > occluded-P (71.93 ppm) > reduced-P (61.72 ppm) > Al-P (46.59 ppm) > saloid-P (20.93 ppm).

Sarkar *et al.*, (2013) studied the distributions and forms of phosphorous in some red soils plateau of West Bengal. They observed that content of saloid-P, Al-P, Fe-P, Ca-P, RS-P and occluded-P ranged between 1.3 - 3.8 ppm, 10.1- 18.3 ppm, 30.5 - 71.8 ppm, 7.3 - 28.6 ppm , 84.5 - 135 ppm and 15.1 - 23.8 ppm respectively.

2.1.2.6 Available potassium and its inorganic fractions:

Mali (1989) analyzed soils from Panvel, Roha, Karjat and Repoli and reported that the average water soluble-K were 82.15, 1.24, 1.22 and 1.17 ppm for Panvel, Roha, Karjat and Repoli, respectively. The average exchangeable-K content was 141.42, 54.24, 51.41 and 35.33 ppm for Panvel, Roha, Karjat and Repoli, respectively.

Modak (1990) examined the physicochemical properties of different soil profile of Konkan region (Roha, Karjat, Repoli and Panvel) and observed that the available potassium content of these four soil varied from 20.30 - 91.58, 91.33 - 108.39 , 28.24 - 62.33 and 250.7 - 260.33 ppm for Karjat, Roha, Repoli and Panvel series respectively. The high K status in Panvel series might be due to accumulation of K containing salts through creek water and may be because of K bearing minerals in soils. The average non-exchangeable potassium content of Karjat (183.63 ppm), Roha (276.25 ppm), Repoli (263.75 ppm) and Panvel (311.25 ppm) series respectively.

Alexander (1991) examined the physico-chemical properties of different soil profile of Konkan region Thane districts (Palghar, Shahapur, Dahanu and Wada). The different potassium fractions of these regions soils was examined by them and reported that the water soluble potassium of surface soil was more and it showed a declining trend with increase in soil depth. Exchangeable potassium content of soil of this region ranged between 45.61 - 223.33 ppm. The results also indicated that that exchangeable K content showed a declining trend with increase in soil depth in case of Palghar and Shahapur soil series while in case of Dahanu and Wada, there was a declining trend at

depth 30-60 cm but increased at 60-90 cm depth. Similar observations were reported by Kadrekar (1977). The non exchangeable potassium content in soil profile at different depth varied from 116.86 - 258.76 ppm. The non exchangeable potassium content in soil profile at different depth didn't show any specific trend.

Pal and Mukhopadhyay (1992) observed that decrease in available potassium content was due to more intensive weathering, release of labile potassium from organic residues, application of potassium fertilizers and upward translocation of potassium from lower depths along with capillary rise of ground water.

Talele *et al.*, (1993) studied the K fractionation in different soils of Maharashtra viz. Panvel (Entisol), Radhanagari (Oxisol), Paud (Inceptisol), Digrag, Badnapur, Latur, Pipri (Vertisols) and Ganeshpur, Hiware (Alfisol). He reported that Entisol soils contain water soluble-K, exchangeable-K, nonexchangeable-K and total K as 0.4, 10.0, 16.7 and 10.90 dg kg⁻¹ respectively. Oxisols soils water-soluble-K, Exchangeable-K, Nonexchangeable-K and Total-K contains 0.6, 26.0, 11.9 and 62.8 dg kg⁻¹ respectively. Vertisol soils contain water soluble-K, exchangeable-K, nonexchangeable-K and total-K in range of 107 - 1.7, 15.2 - 56.5, 61.8 - 162.5 and 684 - 1326 dg kg⁻¹ respectively while Inceptisol soils contain water soluble-K, exchangeable-K, nonexchangeable-K and total-K, were 0.9, 23.4, 5202 and 1120 dg kg⁻¹ respectively. The Alfisol soil contains water soluble-K, exchangeable-K, nonexchangeable-K & total-K ranged between 0.8 - 1.3, 22.7 - 30.5, 159.1 - 190.1 and 1234 - 1432 dg kg⁻¹ respectively.

Bhaskar and Subbaiah (1995) observed very low available potassium content in lateritic soils of Andhra Pradesh, either due to low weathering of coarse size mica or due to presence of small amounts of feldspar as source for bases.

Chavan *et al.*, (1995) from their study found that the average values of potassium content in the lateritic soils of Konkan (M.S.) were 147.30 and 108.40 kg ha⁻¹ at 0-30 and 30-60 cm depth, respectively. A declining trend with depth was also reported.

Santhy *et al.*, (1998) studied on K fractionation in *Vertic Ustropept* soils of Tamilnadu. They reported that water soluble-K, exchangeable-K, nonexchangeable-K, total-K and available-K content 12, 183, 813, 3665, and 198 ppm, respectively.

Das *et al.*, (2000) studied on K fractionation in red and lateritic soil of West Bengal. They reported that watersoluble-K, exchangeable-K, HNO₃ extractable-K, non

exchangeable-K, and total-K content varied from 0.004 - 0.047, 0.11 - 0.51, 0.18 - 0.98, 0.03-2.78 and 17.92 - 90.8 meq.100 g⁻¹ soil respectively. The surface soils contained fewer amounts of all forms of K than subsurface soils except water soluble K.

Setia and Sharma (2004) studied the inorganic K fraction *Typic Ustochrept* soil. They resulted that content water soluble-K (11.0 ppm), exchangeable-K (19.0 ppm), Non-exchangeable-K (623 ppm) and total-K (9125 ppm).

Shinde (2006) from his study on 'physico-chemical properties of lateritic soil from Ratnagiri and Sindhudurga district' and reported an estimate of potassium content in the range of 212.35, 302.40, 201.60 and 282.89 kg ha⁻¹ at 0-30 and 30-60 cm depth, respectively.

Chandrashekhara and Krisnamurthy (2007) studied on quantity intensity relationship of potassium in soils of Andhra Pradesh. He resulted that the water soluble - K, exchangeable - K, non-exchangeable-K and total K varied from 11.3 - 46.2 ppm, 10.2 - 358.9 ppm, 95 -1806 ppm and 1959 – 2852, ppm respectively.

Dhar *et al.*, (2009) studied the different forms of K in soil in Alfisol. They reported the water soluble K content, exchangeable K content, Non-exchangeable K content as 1.56, 4.29, 20.3 ppm respectively.

2.1.2.7. Micronutrient content in soils:

Andhalkar (1984) studied the micro nutrient status of the coastal saline soils and observed that coastal saline soils contain adequate available Mn and Cu. However, deficiency of Fe and Zn was found in some soils both in VRN and VRL zones of konkan which is likely to pose problem in rice cultivation in these soils. He further reported that from VRN zone the content of micronutrients ranges from iron (1.9 - 41.92 ppm), manganese (0.48 - 111.8 ppm), copper (0.08 - 17.4 ppm), and zinc (0.46 - 6.58 ppm) and from VRL zone the content of micronutrients ranges from iron (2.94 - 53.2 ppm), manganese (0.32 - 108.0 ppm), copper (1.02 - 24.66 ppm) and zinc (0.44 - 5.72 ppm).

Bharambe *et al.*, (1990) reported no specific trend of Fe content with the soil depths of Maharashtra. Sankpal (2008) revealed that the Fe content in lateritic soil of Konkan (M.S.) was between 17.42 and 123.30 mg kg⁻¹. Somasundaram *et al.*, (2009) found that the top and slope soils of ravines had more Fe deficiency than other soils. This was probably due to accelerated soil erosion.

Chinchmalatpure *et al.*, (2000) also observed that no specific trend of Mn with depth but they found higher available Mn content in some surface soil samples. This may be due the chelating action of organic compounds released during the decomposition of manures. Singh (2006) found that the average available Mn was in the range of 1.4 - 50 mg kg⁻¹ in the soils of Maharashtra.

Chinchmalatpure *et al.*, (2000) observed that most soil profiles on sandstone land forms were deficient in available Zn as compared to soils derived from basalt due to relatively higher organic carbon content. Mahajan (2001) from his study on 'status and distribution of micronutrients in relation to the properties of lateritic soils in south Konkan (M.S.)' observed that the available Zn of surface and profile soil was 0.255 - 1.769 ppm and 0.142 - 3.750 ppm respectively. He also found an increasing trend of available Zn with slope of soil while a decreasing trend with the soil depth.

Mahajan (2001) Yadav (1988), found the levels of Mn in the lateritic soils of Konkan (M.S.) in the range of 6.93 - 74 mg kg⁻¹ and a decreasing trend of Mn content with soil depth. However, Pereira *et al.* (1983) reported an increasing trend of Mn content with depth in hill soils of Konkan (M.S.) due to the leaching losses from surface layer.

Rajeswar *et al.*, (2009) found a declining trend of available Cu with soil depth due to decrease in organic carbon content in soil profiles. However according to Mehta *et al.*, (1964) the higher values of available Cu in the surface soil might be due to translocation of Cu from lower layers to the surface layers under the influence of vegetation.

Rajeswar *et al.*, (2009) stated an irregular trend of Mn with depth which was due to its presence in reduced forms in the soils while Chavan *et al.*, (1980) observed that the declined trend of Mn with soil depth may be due to decomposition of organic matter and restriction of the movement of bivalent Mn by free lime in profile soils.

Patil *et al.*, (2010) observed that the available Cu content in the lateritic soils of Konkan (M.S.) varied from 1.49 - 9.32 mg kg⁻¹. Gaidhani (2008) from his studies on 'Effect of integrated nutrient management on yield, partitioning and uptake by Rice and on fertility' reported that the range of available Cu in lateritic soils of Konkan (M.S.) was varied from 14.75 - 27.08 mg kg⁻¹. In addition, Singh (2006), in his survey of soils of Maharashtra, observed the overall available Cu in the range of 0.42 - 8.72 mg kg⁻¹.

Patil *et al.*, (2010) reported that the available Zn of lateritic soil in Konkan (M.S.) was in the range of 0.29 - 2.28 mg kg⁻¹. Diwale (1994) found Zn content in lateritic soils in the range of 1.10 - 1.30, 0.60 - 0.90, 0.65 - 0.85 and 0.50 - 0.60 mg kg⁻¹ at respective depths of 0-15, 15-30, 30-45 and 45-60 cm. Mahajan (2001) observed that the Fe content in surface and profile soils of lateritic soils of Konkan (M.S.) was in the range 10.31 - 44.75 mg kg⁻¹ and 5.11 - 47.60 mg kg⁻¹ respectively. Diwan (1982) reported that the higher content of Fe in lateritic soils of Konkan (M.S.) was due to laterization processes in which sesquioxides accumulate to increase the Fe content. In addition, low pH and higher organic matter content of lateritic soil was also responsible for higher Fe values.

2.2. Leaching losses of primary nutrients and pesticides from soils:

The soil type has a great important influence on nutrient and pesticides leaching losses as the movement of these nutrients and pesticides in water is affected by the soil characteristics which define their retention. The extent of leaching of primary nutrients and pesticides is determined by the water movement in soil due to the different physico-chemical characteristics of the various types of soil as well as solubility, adsorptive properties and their respective application rate of respective nutrient and pesticides. Thus it is important to consider the soil properties in any review of nutrient and pesticides movement by water. The related research review has been discussed as below.

2.2.1. Leaching losses of nitrogen from soils:

Karande (1985) conducted a pot experiment in greenhouse to study the effect of potassium levels on nitrogen leaching losses from lateritic soils of Konkan under rice crop. The N leaching loss observed increased with increasing K fertilizers application rate in combination with nitrogen fertilizers from pot under rice crop. He observed that in 70 days, total leaching loss of nitrogen (ammonical + nitrate nitrogen) from rice growing pots ranged between 2.60 - 32.10 percent of applied nitrogen. Highest leaching loss (11.03 meq.l⁻¹.) of total nitrogen was found in the treatment (100:50:50 N:P:K dose). Out of total leaching loss the maximum loss (2.56 - 8.03 meq.l⁻¹.) was found in NH₄-N form as compared to nitrate form (0.95 - 3.36 meq.l⁻¹) in all the treatments. He further revealed that, leaching loss of NH₄-N increased with increase in number days of observation up to 40 days. However after 40 days it showed a decline till in trend

subsequent observation even after application of the remaining split dose of nitrogenous fertilizers. In case of nitrate, he reported that the leaching loss of $\text{NO}_3\text{-N}$ was observed right from the beginning of the first observation at 10 days and it showed increased trend in its loss up to 40 days. However, thereafter it showed decline in trend and it was minimum at 70 days in the last observation.

Mahajan and Tripathi (1991) studied the leaching losses of nitrogen from soil column treated with different N-fertilizer sources (Lac coated Urea, Neem coated Urea, Neem cake coated Urea, Urea super granules and Sulphur coated Urea) under submerged condition. After 61 day of incubation they observed leaching loss of total N (ammonical and nitrate nitrogen) ranged between 19.0 - 67.6 percent of applied nitrogen.

Ali and Singh (1994) reported that the leaching loss of nitrogen was highest (4.2 ppm) upto eighth day after fertilizer application from soil (*Aquic Hapludoll*) of Pantnagar, Nainital under lowland rice crop. Amongst all the fertilizers treatment, the average highest leaching losses of nitrogen (1.6 mg l^{-1}) were observed in splits application of urea treatment while lowest leaching losses (1.5 mg l^{-1}) were observed in USG treated soil with deep placement.

Santra *et al.*, (1994) studied the field experiment on leaching losses of nitrogen from peizzometer which was installed in flooded rice soils (*Haplustalfs*) of Mohanpur, West Bengal. They reported that total N ($\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$) leaching loss content in leachate ranged 10.29 - 18.05 percent and 9.31 - 18.68 percent of the applied nitrogen in different treatment of the *Kharif* and *Rabi* season respectively.

Suresh *et al.*, (1994) studied the dynamics of the different forms of nitrogen in the leachate due to the application of nitrogen through different sources (Prilled Urea, ammonium chloride, neem coated Urea, Urea gypsum and green leaf manure) with wetland rice crop soils (*Typic Ustropept*) of Killikulam, Tamilnadu. They reported that during rice growing period leaching losses of $\text{NH}_4\text{-N}$ during phase-I (first seven days) from rice transplanting was in the range of 5.8 - 7.4 ppm, while it decreased in II phase (i.e from seventh day to 2nd top dressing of N fertilizers) and range in between 2.6 - 5.0 ppm and it was found to be lowest in phase III (i.e from 2nd top dressing to 60th day) in the range of 2.1 - 3.7 ppm due to various treatments. In the same experiment the $\text{NO}_3\text{-N}$

leaching loss in phase I, II and III ranged between 0.39 - 0.67, 0.26 - 0.44 and 0.23 - 0.35 ppm respectively.

The effect of depth of standing water (0, 3, 10 and 30 cm) on leaching losses of nitrogen were studied by Panda (1994) in alluvial (Inceptisol, *Haplaquept*) soil of CRRI Cuttack under rice crop. He reported that total ammonical leaching losses from soil increased with increasing depth of water which ranged between 4.4 - 33.2 percent of applied nitrogen.

Mandal and Kar, (1995) conducted an field experiment in *Ultic Haplustalf* soil under rice-wheat rotation to identify the most efficient method and to fix the efficient schedule for nitrogen application method. The study was carried out for two years in which nitrogen fertilizer was applied (@ 120 kg ha⁻¹). From the two years data, it was observed that the average leaching losses of nitrogen from lateritic soil under rice crop ranged between 37.70 - 55.58 kg ha⁻¹ due to different methods and schedule of fertilizers application. They further concluded that leaching losses could be minimized upto 33 percent due to the band placement and more number of splits doses of nitrogen fertilizers than the traditional 2 split broadcast method of fertilizer application.

Medhi *et al.*, (1996) studied the effect of incorporation of organic and inorganic sources of N on leaching loss of nitrogen. They revealed that Prilled urea showed higher NH₄⁺-N leaching loss as compared to incorporation of organic + inorganic sources of N. Prilled urea treatment showed higher leaching losses of NH₄⁺-N than did organic sources at 2 weeks after flooding.

Mandal and Kabir, (1997) studied the effect of boron and molybdenum released of mineral-N in 3 contrasting soils of Bangladesh and revealed that the leaching loss of NH₄⁺-N in coastal saline soil incubated with ammonium chloride, ammonium sulphate and urea in presence of boron and molybdenum showed a very sharp decline at 7th day of incubation. Thereafter, the change was negligible and remains almost static upto 42 days of incubation in all the leachate irrespective of the sources of nitrogen used. The amount of NO₃-N leaching lost in three soils followed the sequence coastal flood plain soil > Alluvial soil > Acid sulphate soil. The NO₃-N leaching loss varied with sources of nitrogen and followed the sequence urea > ammonium chloride > ammonium sulphate and ammonium chloride > urea >

ammonium sulphate, when the soils were incubated with boron and molybdenum, respectively.

Purakayastha and Katyal (1998) conducted the green house experiment with a view to evaluate the different chemical additives on efficiency of urea in wet season rice Vertisol, Alfisol and Inceptisol soil type. The pooled data reported that the maximum amount of nitrogen was lost after first day of fertilization from Alfisol (5.6 ppm) followed by Inceptisol (4.3 ppm) and Vertisol (4.0 ppm) of applied Nitrogen with various treatment.

Velu and Ramanathan (1998) conducted a pot culture experiment to study the forms and magnitude of leaching loss of N in wetland rice light and heavy textured soils. The results indicated that light textured Medukkur series registered higher leaching loss of N under all N application rates (@ 0, 51, 102 and 150 kg ha⁻¹) than the heavy textured Kalathur and Padugai series soils. Out of total leaching loss about 77 percent was in the form of as ammonium-N and 11.9 as nitrate-N. The mean leaching loss of ammonium-N was highest (27.9 mg pot⁻¹) in Madukkar series followed by Kalathur (18.2 mg pot⁻¹) and Padugai (18.2 mg pot⁻¹) while in case mean nitrate-N leaching, it was relatively higher in Kalathur series (3.92 mg pot⁻¹) followed by Padugai (3.32 mg pot⁻¹) and Mudukkar series (2.98 mg pot⁻¹).

Pramanik and Murthy (2000) studied the nitrogen mineralization from neem extract coated urea viz prilled urea in rainfed lowland rice coastal soil in Andaman. The results indicated that the leaching loss of NH₄⁺-N with prilled urea declines sharply from 7th day onwards from saline lowland rice soil in Andaman, while the use of urea coated with neem extract (nimin) retarded the urea hydrolysis and maintaining higher leachate NH₄⁺-N concentration upto 21st days.

The transport of USGs (urea super granules) with water in an Inceptisols soil column under flooded condition was studied by Mishra *et al.* (2000). They reported that about 54.6 percent of applied USGs leached down with percolating water through 0.09 m soil column in the soluble NH₄⁺-N form whereas nitrate leaching loss with percolating water was found almost zero at same depth because of low nitrification reaction under flooded condition as compared to ammonification reaction.

Velu and Ramanathan (2000) reported that light textured (Medukkur series) registered higher leaching loss of N than the heavy textured (Kalathur and Padugai

series) soils in pot culture experiment under rice crop with various N fertilizers treatment (prilled urea, Neem coated urea, Lac coated urea). The average leaching loss ($\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$) was highest (8.0 - 57.4 mg pot⁻¹) in Madukkar series followed by Kalathur (8.0 - 37.0 mg pot⁻¹) and Padugai (7.1 - 29.9 mg pot⁻¹)

Shibu and Ghuman, (2001) studied the leaching losses of applied nitrogen from undisturbed alluvial soil columns. They showed that leaching losses of the total N ($\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$) from puddled soil under continuous flooding (2.67 percent) was comparatively lesser than under intermittent flooding (8.14 percent) of applied nitrogen.

Shibu and Ghuman, (2003) studied the nitrate nitrogen leaching losses from undisturbed soil column. They showed that leaching loss of $\text{NO}_3\text{-N}$ ranged from 2.9 - 20.7 percent due to the application of KNO_3 @ 180 Kg ha⁻¹ to column.

Denesh *et al.*, (2004) studied on nitrogen losses in drum seeded rice with application of recommended dose of nitrogen in three split doses (50:25:25) in red clay loam soil. They recorded that leaching losses of the total N ($\text{NH}_4^+\text{-N} + \text{NO}_3\text{-N}$) in leachate at stage before first top dress-I, 4th DAFTD (day after first top dress)- II, 8th DAFTD - III, DASTD (before second top dress) - IV, 4th DASTD - V, 8th DASTD - VI, DATTD (before third top dress)-VII, 4th DATTD - VIII, 8th DATTD - XI, were 10.26, 11.2, 10.26, 9.33, 13.7, 14.00, 7.47, 14.00 and 15.90 ppm respectively. The results suggested that existing irrigation and N application method to rice i.e MSW (maintaining standing water 2.5 cm) + PU 100 percent recommended N applied as 50 percent at sowing + 25 percent at tillering + 25 percent at panicle initiation recorded the higher N leaching losses than compared to the conventional (two splits nitrogen application) method.

Jena *et al.*, (2004) studied the transport of nitrogen (USGs @ 76 kg ha⁻¹) in rice flooded soil. They computed that the downward velocity of $\text{NH}_4^+\text{-N}$ with water was in range of 1.6×10^{-3} m hr⁻¹ to 1.5×10^{-3} m hr⁻¹ in soil profile. They reported that out of total applied nitrogen leaching loss 20 - 55 percent was detected in soil leachate in the form of $\text{NH}_4^+\text{-N}$ collected at 0.20 m soil depth due to downward movement with percolating water. But no $\text{NO}_3\text{-N}$ form was detected in leacheate at the same depth. Similar results were reported Phillips and Burton (2005).

Singh *et al.*, (2006) conducted a study on the leaching losses of N-fertilizers from a 100 cm long soil column under lowland moisture regime having sandy loam and clay loam soils of Punjab. They reported that total NO₃-N leaching loss from column accounted 26.6 percent of applied fertilizer while the total leaching losses of N (ammonical + nitrate) amounted to 38.6 percent of the applied N.

Lysimeter experiment with undisturbed soil profile were conducted by Xiao-Zhi *et al.*, (2007) to study the nitrogen cycling and its losses in soil with various rates of nitrogen (@ 275 to 550 kg ha⁻¹). From the three year pooled data it is observed that that average leaching losses of total N (ammonical + nitrate) ranged between 33.7 - 55.6 kg ha⁻¹ in various treatments.

Masthanareddy *et al.*, (2009) conducted a field experiment in Karnataka to study the nitrogen leaching losses from medium deep black clay (Vertisol) soils lowland rice crop with various combinations of N, P and K. From the two season (*kharif and rabi*) data they revealed that the average total N (ammonical + nitrate) leaching losses ranged between 3.6 - 7.0 percent of applied nitrogen.

2.2.2. Leaching losses of phosphorus from soils:

Phosphorous leaching losses with water was about 2.5 times more in the wet season than in the dry season as reported by Katyal and Venkatramayya (1983). They further reported that the leaching losses of phosphorous from P deficient submerged Vertisols during wet and dry season under rice crop ranged between 0.04 - 0.16 and 0.02 - 0.06 ppm respectively.

Sharma and Mishra (1988) showed that leaching loss of P from lowland rice ranged from 0.3 - 0.5 ppm which increased rapidly during first 10 days followed by a gradual increase upto the 40th day and showed decrease thereafter.

Medhi *et al.*, (1996) conducted an incubation experiment for 200 days to study the effect of incorporation of organic and inorganic sources on leaching losses of P in leachate. They reported that the concentration of P in leachate were higher with prilled Urea and organic sources than control. They further reported that in 200 days of incubation average P content of leachate was 0.03 ppm.

An incubation experiment of 29 days was conducted by Muralidhar *et al.*, (1999) to study the effect of salinity level on the release of nutrients in leached water from saline soil. They observed that higher leaching losses of phosphorous (0.05 - 0.09 ppm) during 3 to 9 days after incubation and then decreased upto 0.01 ppm as time

increased upto the 29th day. They further reported that as salinity increases the leaching losses of P decreases.

Delcampillo *et al.*, (1999) conducted long-term incubation experiments to evaluate the extent of leaching losses of phosphorus from acid sandy soils with various rate of fertilization. They observed that the total P leached in the leaching experiments ranged between 1.13 - 1.22 percent of applied P fertilizers with different treatment of fertilizer rate.

Cho *et al.*, (2000) studied the balance of phosphorus in a loamy clay soils from central Korea under paddy crop. They estimated that about 0.2 kg P ha⁻¹ of phosphorus leached from irrigated paddy per rice cropping season.

Simard *et al.*, (2000) reported that total P leaching losses from poorly drained clay soils ranges from 0.01 - 1.17 ppm throughout the rice growing period. It was found higher during the initial period and decreased thereafter.

The amount of phosphorous in leachate during lowland rice soil ranged between 0.200 - 0.025 ppm when P fertilizer applied @ 90 kg P₂O₅ acre⁻¹ was observed by Wilson *et al.* (2000) while Pheav *et al.*, (2002) estimated the range of phosphorous in leachate from lowland rice ecosystem and found that 0.14 - 0.10 ppm P was lost in the leachate. They further estimated the total leaching loss of phosphorus 0.9 kg P ha⁻¹ from the soil under lowland rice ecosystem of Cambodia.

The effect of phosphate fertilizer application with various rates on phosphorus (P) leaching losses from soils in Taihu Lake Region under paddy was examined by Zhang *et al.*, (2003). The results indicated that average phosphorous content in lechate during the rice growth was 0.25 ppm, while the average total leaching losses of phosphorous was upto 0.74 kg ha⁻¹.

Zhang *et al.*, (2004) studied the leaching loss of P from a rice field in Taihu Lake basin. They reported that phosphorous leaching loss into ground water under lowland rice crop was very little i.e. 1.5 percent of added P fertilizer.

Cao *et al.*, (2005) studied P losses from different cropping systems, including mulberry, and wheat-rice rotation, for 5 years. They reported Phosphorus leaching losses were greatest in mulberry fields (1.1 kg ha⁻¹ in 4 months), followed by wheat and paddy rice (0.84 kg P ha⁻¹)

Pheav *et al.*, (2005) studied the phosphorus mass balances for successive crops in sandy soil under *rainfed* rice. They estimated that the average P leaching losses was

about 0.1 kg ha⁻¹ per crop from application of fertilizers @ 33.0 kg P ha⁻¹ to the sandy soil of Prateah Lang under rice crop.

Zhang *et al.*, (2005) studied the effects of agricultural production and various rate of fertilizer application on phosphorus leaching losses from soils. The results revealed that the average concentration of P in lecheate samples were 0.703, 0.763, 0.870, and 1.292 ppm, when single superphosphate fertilizer were applied @ 0, 30, 150 and 300 kg P ha⁻¹ for rice respectively which showed that phosphorus leaching losses increased with increasing rate of fertilizers application. They further reported that phosphorus leaching losses from vegetable fields was 0.27 percent of applied P, which was two times higher than that lost from the rice-wheat rotation system.

Xia *et al.*, (2008) studied the leaching losses of phosphorus from the watershed soils under different farming practices with various rate of P fertilizer application. They observed that phosphorous leaching losses from lowland paddy field were 0.13, 0.50, 0.94, 3.02 and 5.97 kg P ha⁻¹, with application @ of 0, 25, 60, 120, and 240 kg P ha⁻¹ respectively which showed the increasing rate of phosphorous leaching losses with increasing rate of fertilizers application.

Shedeed *et al.*, (2009) studied the nutrient movement in sandy soil under tomato crop. They reported that leaching losses of phosphorous below 25 cm depth with water was higher due to fertilizers application @ 50, 75 and 100 percent recommended NPK dose treatment. They further reported that, the P content of lecheate due to various rate of fertilizers application ranged between 8 - 15 ppm which is more than the initial control value (3.2ppm).

Sitthaphanit *et al.*, (2009) conducted a lysimeter experiment with maize crop to study the fertilizers strategies for improved nutrient use efficiency on sandy soils (*Oxis Paleustult*) in high rainfall regimes at Khon Kaen at Thailand. They reported that P leaching loss mg per column ranged between 7.9 mg - 61.8 mg.

Lee *et al.*, (2010) conducted lysimeter study to evaluate P leaching loss under Chinese cabbage and reported that leaching losses of P ranged between 0.13 - 0.24 ppm when P fertilizers were applied @ 2.5 - 14.3 kg ha⁻¹ while Gamage *et al.*, (2011) reported the average phosphate leaching loss within 200 day from lysimeter was 0.03 ppm.

Jiang *et al.*, (2013) studied the accumulation and leaching risk of soil phosphorus in Lei Bamboo Stands in the upper reaches of Taihu Lake. Phosphorus accumulation and losses were measured in the soils and they reported that total P

leaching loads via. Infiltration and runoff water in the treatments applied P ranged from 4.32 - 7.77 kg ha⁻¹, which accounted for 5.3 - 7.5 percent of total P rates applied.

Leaching losses of P from soil under paddy crop increased as phosphorus fertilizer application rate increased as reported by Wang *et al.*, (2013). They further observed that P leaching loss soil under paddy in the superphosphate treatments varied from < 0.01 - 0.05 ppm whereas no P was found in paddy leachate when no P fertilizer was applied.

2.2.3 Leaching losses of potassium soils:

Karande (1985) conducted a pot experiment of potassium leaching losses as affected by different levels (0 - 50 kg ha⁻¹) with N from lateritic soils of Konkan under rice crop. He reported that the total leaching loss of potassium occurred up to 70 days crop growth period ranged between 2.56 - 4.52 meq.l⁻¹ with different treatments. The leaching loss of K was noticed as maximum (0.64 - 0.87 meq.l⁻¹) at 10 days and afterwards it showed a declining trend gradually in subsequent observations and it was recorded declining minimum (0.10 - 0.40 meq.l⁻¹) at 70 days with different treatments. The maximum amount of leaching loss of K was noticed in N100 P50 K50 treatment throughout the rice growing period.

Acid lateritic soils and sandy soil containing Kaolinitic clay minerals which have low cation exchange capacity are more prone for leaching losses of nutrients as reported by Sharply *et al.*, (1990). The results indicated that rates of potassium leaching from these soils ranged between (22 -133 kg ha⁻¹yr⁻¹).

Laxminarayana *et al.*, (1990) conducted an experiment to study the leaching losses of K from coastal sandy soil column with treatment of potassium fertilizers sources (KCl and K₂SO₄) and they reported that leaching losses of K within 80 days were 35.5 and 53.3 percent of applied K from KCl and K₂SO₄ respectively.

The K leaching loss from Red-Yellow Podsol soil in Northeast Brazil under sugarcane due to percolation below 100 cm was observed by Salcedo and Sampaio (1991). The total leaching loss was observed 9 kg ha⁻¹ when sugarcane crop fertilized with 100 kg ha⁻¹ of K₂O. However, K losses, by leaching, varying of 64 - 136 kg ha⁻¹ were verified by Kwong and Deville (1984) in lysimeters cultivated with sugarcane, which were fertilized annually with high doses of KCl, equivalent to 285 kg ha⁻¹ year⁻¹ of K₂O.

Wong *et al.*, (1992) conducted a lysimeter experiment under maize and rice crop to study the leaching losses of potassium. From pooled data it was found that the K losses were less than 10 percent of the exchangeable K of the soil and added fertilizer.

Bajwa *et al.*, (1993) conducted a leaching experiment in column for studying the effect of applied potassium (@ 10 percent KCl solution) on leaching loss of potassium from two *Illitic* (sandy loam and sandy soil) soil columns of Ludhiana, Punjab. The results indicated that leaching losses of potassium with percolating water from soil column ranged between 0.2 - 3.1 meq.l⁻¹ and 1.2 - 3.4 meq.l⁻¹ from sandy loam and sandy soil column respectively which showed that leaching losses of phosphorous are higher in sandy soil as compared to sandy loam soil.

The effect of various nitrogen fertilizers sources (prilled urea, Ammonium chloride, and Neem coated urea) in combination with potassium fertilizer application @ 50 kg ha⁻¹ on leaching losses trend of potassium from soil (*Typic Ustropept*) under lowland rice was studied by Suresh *et al.*, (1993). The pooled analyzed data of two seasons (*kharif and Rabi*) reported by them showed that at basal dose of nitrogen application the leaching rate of potassium was found highest (1.08 - 1.99 *Rabi* and 0.84 - 1.42 kg ha⁻¹ *kharif*) which decreased at first top dressing of nitrogen (0.83 - 1.59 kg ha⁻¹ *Rabi* and 0.58 - 1.00 kg ha⁻¹ *kharif*) and found lowest (0.68 - 1.29 kg ha⁻¹ *Rabi* ,0.54 - 0.91 kg ha⁻¹ *kharif*) at second top dressing of nitrogen .

A lysimeter experiment was carried out by Oliveira *et al.*, (2002) with sugarcane aiming to evaluate the leaching of K from soil under sugarcane crop. During the experimental period the total volume of water received by the sugarcane-soil system was 2,015 mm, with 1,255 mm as precipitation and 760 mm as irrigation. The mean losses of K were of 13 kg ha⁻¹.

Askergaard *et al.*, (2004) studies sustainable management of potassium leaching in crop rotation experiments. They showed that the average K leaching with water varied from 1 kg ha⁻¹ on loamy soil (24 percent clay) to 46 kg ha⁻¹ on a coarse sandy soil.

Phillips and Burton (2005) studied the nutrient leaching in undisturbed cores of acidic sandy *Podosols* following simultaneous potassium and diammonium phosphate application. They resulted that approximately 21 percent (100 mg), 11 percent (105 mg)

and 31 percent (615mg) of potassium leached from the soil cores with percolating water out of the K applied @ 50, 100 and 500 kg ha⁻¹ rates respectively.

Singh, *et al.*, (2005) conducted an experiment on leaching losses of potassium from column having loamy sand soil with different potassium fertilizers. They found that leaching losses of potassium from fertilizers treated column was higher (117.5 mg) than untreated control soil columns i.e. 27.9 mg. They further reported that within 21 days of continuous leaching the 45.5, 44.8 and 42.0 percent of applied potassium was leached from columns in leachate from KCl, KNO₃ and K₂SO₄ treated soil columns respectively which showed that KCl fertilizer application leads to highest leaching losses as compared to other fertilizers.

Tejada *et al.*, (2005) studied the effect of application of two fertilizers on nutrient leaching losses from soil under wheat crop. Results showed that the total leaching losses of K for the treatment with inorganic fertilizers was 29.6 percent of applied quantity.

The leaching losses of potassium from organic amendment treated (rice straw, wheat straw, poultry manure, FYM and green manure) soil column and inorganic fertilizer treated column soils under flooded and upland moisture regimes was studied by Singh *et al.*, (2005). They found that leaching losses of potassium from organic sources was less than inorganic sources. They further reported that potassium leaching in 12 irrigation from inorganic fertilizers treated soil column ranged between 22.2 - 15.8 percent of applied quantity whereas it was found only 1.2 - 17.3 percent from organic (poultry manure, FYM) treated soil column. Among the organic sources the highest (17.3 - 8.8 percent) leaching losses of potassium were recorded from poultry manure treated soil column whereas the lowest (1.2 - 1.8 percent) amount was found from FYM treated soil column. They also reported that leaching losses of potassium was higher from sandy loam soil column as compared to loam soil column in all the treatments.

The potassium leaching losses from potassium rich saline soil of Kalipatnam, West Godavari district of Andhra Pradesh was examined by Sreenivas *et al.*, (2008) by using good quality of water. They reported that leaching losses of potassium due to application of good quality of water application rate @ of 10, 15, 20, 25 and 30 cm was 9.30, 3.32, 3.32, 1.83, 1.33 and 1.16 meq. l⁻¹ respectively.

Sitthaphanit *et al.*, (2009) conducted a lysimeter experiment from sandy soils (*Oxic Paleustult*) of high rainfall regimes area at Khon Kaen, Thailand, under maize crop to study the fertilizers nutrient use efficiency and reported that K leaching losses per column ranged between 184 - 400 mg in various treatment of fertilizers combinations.

The effect of various chemical fertilizer applications on leaching losses of potassium from soil was examined by Lee *et al.*, (2010) by using the lysimeter in the Chinese cabbage growing soil. They reported that average K leaching losses with water ranged between 9.9 to 3.0 kg ha⁻¹ having leachate K concentration in between 1.21 to 1.31 ppm throughout the growing period.

2.2.4 Leaching losses of pesticides from soils

Sheets *et al.*, (1972) conducted an experiment to study leaching losses of pesticides used in cotton crop. The pesticides applied to cotton by spray method. Their results showed that total leaching losses of Toxaphene,, DDT, Trifluraline, Methyl parathion and Voxaphene from the soil under cotton crop were found less than 1, less than 11, 0.9, 0.25 and 2.831 percent of applied quantity. During the cotton growing period the average pesticides content in leachate were ranged 0.35 - 65 ppb which causes contamination of surface and ground water.

Caro *et al.*, (1973) studied the leaching loss of Carbofuron from lowland rice soil. They reported that leaching loss of Carbofuron ranged from 0.5 - 2.0 percent of the applied quantity.

Willis *et al.*, (1975) conducted a field experiment to evaluate the leaching losses of pesticides with leaching water. This experiment was continued up to three years with application of different pesticides (Diuron, Linuron, Fenac and Trifluralin) and from the three years data they reported that the average leaching losses of Diuron, Linuron, Fenac, and Trifluralin from soil were 0.12, 0.30, 2.90, and 0.05 percent of the applied pesticides respectively.

Walter-Echols and Lichtenstein (1978) studied on the fate of phorate in a soil-water-plant system using Elodea as plant in agricultural flooded loam soil system. They reported that Phorate was much more persistent under flooded than under non flooded conditions. The results showed that within fourteen days after application, leached water contained 39 percent of the applied Phorate.

Wauchope (1978) studied pesticide leaching loss with water draining from agricultural fields. He reported that total losses of pesticides in runoff water are 0.5 percent or less of the amount applied within one to two weeks after application.

An incubation study was conducted in glass chamber with soil under rice by Isensee, *et al.*, (1982) to study the fate of 3, 4-Dichloroaniline (DCA) in rice fields. The soil from rice field filled in a glass chamber with planted rice and treated with 10 ppm DCA used for incubation experiment. The percent of DCA leached with water was of 2.8 percent of the total applied into water upto the planted rice reached the two-leaf stage.

Radder *et al.*, (1986) conducted a leaching column experiment with application, 30 mg of Carbaryl and 30 mg Phorate per column, having red, laterite, black and saline alkali soil of Karnataka. The percent of Phorate leached was found in order red (63) > lateritic (43) > black (28) > saline soil (10) and Carbaryl percent leaching loss showed the trend red (72) > Lateritic (62) > black (30) > saline soil (9) within 72 hours of application.

Ross and Sava (1986) studied the fate of two herbicides, (granular Thiobencarb and Molinate), broadcast in rice fields. They reported that maximum Thiobencarb and Molinate concentrations in leachate at thirty-two days after application were 576 ppm and 3430 $\mu\text{g l}^{-1}$ respectively. The mass balance budget indicated that Thiobencarb and Molinate were predominantly lost in leachate from 34 and 17 percent respectively.

Redder *et al.*, (1988) reported the amount of Carbofuron recorded from black, Red and Laterite soil after four weeks. The average Carbofuron level in paddy leached water in black soil during the four week was 2.56 ppm when insecticides were incorporated into surface soil and 3.60 when applied as broadcast in paddy water. They also concluded that leaching loss of pesticides found higher with water broadcast method than soil surface application.

Radder *et al.*, (1989) conducted a leaching column experiment with application certain insecticide and fungicide @ 30 mg per column to study the persistence and degradation of certain insecticide and fungicide in selected soils of Karnataka. They reported the percent leaching loss of Fenitrothion observed was 36, 33, 19 and 9 in red, laterite, black and saline alkali soil, respectively while the percentage of Phorate

leached was 28, 63, 43 and 10 percent in black, red, laterite and saline alkali soil respectively.

Nicosia *et al.*, (1990) studied off-field movement and dissipation of soil incorporated Carbofuron from three commercial rice fields, and potential discharge in agriculture runoff water they reported that a total of 1.71, 5.40 and 11.03 percent of Carbofuron applied to three rice fields were leached with water within 80 days. They reported that maximum concentrations of Carbofuron in paddy leachate water ranged from 24.5 - 38.2 $\mu\text{g l}^{-1}$ upto 28th day while the concentration found decreased ranged from 0.7 - 1.7 $\mu\text{g l}^{-1}$ at the end of paddy crop.

Parama *et al.*, (1991) studied on leaching rate and distribution of Carbaryl and phorate in soil columns. They revealed that the leaching of both the pesticides was more in coarse-textured red and Laterite soils than that in fine - textured black and saline-alkali soils. In saline-alkali soils no loss of the pesticides occurred during first 18 hours. The content of Carbaryl and Phorate in leachate followed the order: red soil > laterite soil > black soil > saline-alkali soil.

Bastien and Madramootoo (1992) studied the leaching losses of applied pesticides (Metribuzin @ 2 kg ha^{-1} , Fenvelarate @ 1000 mg kg ha^{-1} , Aldicarb @ 2 kg ha^{-1} and Phorate @ 10 kg ha^{-1}) from potato growing *Podzols*. They reported that Metribuzin, Fenvelarate, Aldicarb and Phorate concentration in leachate ranges 3.47-0.16 $\mu\text{g l}^{-1}$, 0.00 $\mu\text{g l}^{-1}$, 0.05 $\mu\text{g l}^{-1}$ and 0.00 $\mu\text{g l}^{-1}$ respectively.

Castaneda and Bhuiyan (1996) studied the groundwater contamination by rice field pesticide and some influencing factors. They reported that leaching loss of six common pesticide from rice growing profile into groundwater i.e. tube well of Philippines from 0.002 ppb for Chloropyrifos, 0.209 ppb for Monocrotophos and 0.207 ppb for Carbofuron due to use of pesticides in rice.

Experiment was conducted by Sundaram (1994) with using undisturbed cores of two different soils which repacked in column to study the sorption and movement of pesticides within soil profile. They reported that soil having high infiltration rate contain higher amount of pesticides residues in leachate than soil having lower infiltration rate. They also showed that leaching of pesticides decreased in soil column with increasing organic matter as well as clay content in soil. Among the pesticides

used for the experiments followed the residues contain pattern in leachate Terbufos < Phorate < 2-4-D < Atrazine < Metsulfuron methyl.

The effect of various organic material (FYM, sewage sludge and poultry manure) application on adsorption-desorption of three Carbamate pesticides (Oxamyl i.e. P-I, Thioacetimidate i.e. P-II and N-phenyl (Ethyl carbomoyl) Propyl Carbamate i.e. P-III) on six soil sample of Aligarh district were studied by Bansal (2004). He observed that leaching losses of pesticide in unamended soil was higher than in amended soil. The order in unammended soil followed the pattern poultry manure > FYM > sewage sludge. The amended soil the pattern was observed to be II > I > III.

A laboratory lysimeter incubation study was conducted by Tariq *et al.*, (2006) having sandy loam soil (*Typic Ustocurepts*) of Punjab under the cotton crop to study the effect of temperature, moisture, and microbial activity on the degradation and persistence of cotton pesticides (i.e. Carbofuran and Monocrotophos). In order to assess the quantity of leaching amount of pesticides from cotton growing soil, the leachate sample collected from lysimeters on days 49, 52, 59, 73, 100, 113, and 119 against the pesticide application on days after the sowing of cotton. The average amount of Carbofuran and Monocrotophos were detected in the leachate samples 2.34 and 2.6 $\mu\text{g l}^{-1}$ respectively.

An incubation study was conducted by Choudhary *et al.*, (2006) to study the controlled leaching loss of Carbofuran in water from some polymetric matrices. The incorporation of different clay formulation (Kaolinitic clay, Bentonitic clay and fuller earth) in an incubations polymatrices affects the leaching losses amount of Carbofuran. The leaching losses pesticides amount was found higher from Kaolinitic clay treated polymatrices as compared to Bentonitic and fuller earth clay formulation treated polymatrices. They further reported that the total amount of leaching loss of Carbofuran at the end of 67th day of incubation in leachate ranged between 0.10-0.80 percent of applied dose as affected by incorporation of different clay formulation (Kaolinitic clay, Bentonitic clay and fuller earth).

Kumar *et al.*, (2006) studied the controlled release of Carbofuran into water from polymetric matrices. They reported that released Carbofuran in leaching water beyond 63rd incubation days. They observed that movement of Carbofuran in matrices was slowed down with increase in clay content.

A level IV fugacity model was used by Paraíba *et al.*, (2007) to study the fate of the insecticide Carbofuran in a simulated field under rice crop. They resulted that total amount of Carbofuran leached with water were 2.0 C mol m^{-3} and $0.00 \text{ C mol m}^{-3}$ after 100 and 800 hrs, respectively. These results showed that the complete leaching loss of water soluble Carbofuran of within 800 hours of application.

Pesticides leaching lysimeters study was conducted by Martins *et al.*, (2007) in simulated Oxisol soil. The results of leachate analysis showed that around 6 percent of Carbofuran leached with water from the total Carbofuran applied while the other pesticide leaching percent were viz. 0.13, 0.06, 0.04 and 0.03 percent of applied dose Carbendazim, Diuron, Endosulphon and Metolachlor respectively. The leaching loss of Chloropyriphos pesticide from lysimeter in leachate was not observed up to the end of experiment.

Pany *et al.* (2008) conducted experiment with the various rate of application (@ 1, 1.5 and $3 \text{ kg a.i. ha}^{-1}$) studied the persistence of Phorate in leached water from rice field of Orissa Bhubaneswar . They reported that leaching loss of phorate in lechate from field of rice at 3, 7 and 15 day was in the range of 0.11 - 0.20, 0.08 - 0.14 and 0.03 - 0.06 ppm respectively.

Sridevi *et al.*, (2008) reported that the leaching losses of applied pesticides (Phorate @ $1 \text{ kg a.i. ha}^{-1}$) under paddy crop and observed the pattern red sandy loam > black sandy loam > clayey alkaline soil which shows that the leaching losses of pesticides decreased with increasing clay content in soil and higher in red sandy loam soil.

The downward movement of Carbofuran with water within 14 day in soils from Bagan Datoh Malaysia using leaching columns was studied by Farahani *et al.*, (2008) and observed that Carbofuran leaching losses was higher (41.7 percent) in disturbed soil containing leaching column as compared to undisturbed soil containing soil columns (3.6 percent). They further reported that more Carbofuran content was observed in the leachate of the Labu sandy soil column as compared to Bagan Datoh clay soil column.

Fenoll *et al.*, (2010) conducted a laboratory leaching column study having clay loam soil under pepper cultivation to determine the leaching potential of insecticides and fungicides (Pyridaben, Pyriproxyfen, Tebufenpyrad, Buprofezin and Pirimicarb

and insecticides and acaricides (Azoxystrobin, Kresoxim-Methyl, Hexaconazole, Tebuconazole, Triadimenol) and Pyrimethanil (Fungicides) under pepper cultivation. For this purpose, columns filled with 150 g of a clay loam soil and treated with 100 mg of each pesticide then eluted with 600 ml of 0.01M CaCl₂ for 10 days. They observed that the total percent leaching loss of pesticides in leachate were 48, 41, 6, less than 2 percent, and less than 2 percent Pirimicarb, Triadimenol, Pyrimethanil, Hexaconazole and Tebuconazole respectively.

Bansal (2011) conducted a pot culture incubation experiment to study the sorption -desorption of three carbamate pesticides in six type's soils from India (Bangalore S₁-, Aligarh S₂, Kota S₃, Jhansi S₄, Doiawala S₅ and Ludhiana S₆). Incubated pot treated with Carbufuron @ 50 mg kg⁻¹ of soil and estimated the leaching loss of pesticides upto 91 days. They observed that Carbofuron leaching losses from different soil types were in the range of 30 - 46 percent of amount applied, and the leaching of pesticide was in the order of soil S₆ > S₂ > S₄ > S₁ > S₅ > S₃.

Chowdhury *et al.*, (2012) conducted a field experiment at the Savar and Dhamrai Upazilas, Bangladesh find out the leaching loss of applied Organophosphorus and Carbamate Pesticides (Chlorpyrifos, Malathion, Diazinon, Carbamate, Carbaryl and Carbofuran from the soils under paddy and vegetable crop. The results showed that Diazinon and Carbofuran content in leachate ranges between 0.6 - 0.9 µg l⁻¹ and 105.2 - 198.7 µg l⁻¹, respectively while Malathion was detected in leachate was 105.2 µg l⁻¹. Carbaryl pesticide leaching losses ranged between 14.1 - 18.1 µg l⁻¹. Chlorpyrifos was not detected in any leachate sample.

Janaki *et al.*, (2012) studied the adsorption and desorption behavior of Alachlor in laboratory having different soils (red soils, black soils and peat soil) of Tamilnadu. The results indicated that the average leaching loss of Alachlor leached from soil was in the range between 62 - 90 percent in different soils. They further reported that highest leaching losses were occurred in red soil followed by black soil and found lowest in peat soil.

2.3. Effect of pesticides on availability of primary nutrients:

Thus it also acts as region of greatest activity of soil fauna and flora and provides a platform for interaction of insecticide residues with them. The indiscriminate use of pesticides disturbs the soil biological environment leading to infertility of soil.

Therefore, it is important to study the possible effects of specific pesticides on availability of nutrient to crops. Scientists have done much work discussed below on knowledge of pesticide and their effects on soil nutrient availability.

Arora and Gaur (1979) studied the effect of different pesticides (BHC and Phorate) on availability of phosphorous. They found that insecticides brought about a significant rise in the availability of soluble P due to the greater stimulation of the activities of phosphate solubilizing/mineralizing microorganisms. They reported the higher content of soil available P in pesticides treated soil than the control i.e. pesticide untreated treatment.

Greenhouse experiment was conducted by Tirol *et al.*, (1981) to study the effects of Carbofuran with various rates (@10, 20, 50 and 100 ppm a.i. kg⁻¹) on availability of nitrogen in soil under submerged conditions. They reported that the addition of Carbofuran in soil at all the rates increased available nitrogen content due to enhancement of nitrifying activity as compared to control treatment in flooded soil. They further reported that nitrifying activity increased with increasing Carbofuran concentration as compared to the pesticide untreated treatment.

Mahapatra and Rao (1981) studied the influence of Hexacyclohexane on the nitrogen availability in rice rhizosphere soil. They observed that after HCH application, stimulation of rhizospheric biological nitrogen fixation was observed in the field at 55 days and 87 days. This might be due to retarded the drop in redox potential of the rhizosphere soil favored the growth of populations of *Azospirillum* and *Azotobacter* which results in a long-lasting Rao *et al.*, (1983) observed the similar results.

An incubation experiment by using rice rhizosphere soil was conducted by Ramakrishna and Sethunathan (1982) to study the effect of the application of the insecticide Carbofuran (technical or formulated) at varying rate (@10 and 100 ppm ug ml⁻¹a.i.) on nitrogen availability. They reported that technical Carbofuran as well as Furadan upto the application rate @ 20 ppm of soil increased NO₃⁻ N (2.1mg g⁻¹) in rhizosphere soil at 30 days which is higher than the control NO₃⁻ N value i. e. (0.9 mg g⁻¹). They further reported that Carbofuron application above the 20 ppm rate results into decreased the available nitrogen (nitrate) as compare to control.

Nayak and Rao (1982) studied on pesticides and heterotrophic nitrogen fixation in soil (Alluvial, Laterite, and Acid sulfate soils) under paddy crop. They observed

positive effects of Benomyl and Carbofuran on biological nitrogen fixation when applied to Alluvial, Laterite, and Acid sulfate soils @ recommended dose.

Singh *et al.*, (1985) studied effect of different doses (5.0 - 500 ppm) of nematicide (Carbofuron and Oxamyl) on availability of soil N in the soil under tomato crop. They observed that available N content in soil increased with the application of nematicides upto certain limit of doses. A decline in availability of N was observed when application rate exceeds above 10 ppm in case of Carbofuron and 50 ppm in case of Oxamyl as compared to control.

Shahaat *et al.*, (1987) studied the effect of Carbamate and synthetic Pyrethroid pesticides on some soil microbial activities and nutrient availability. They reported that insecticidal residues and degradation products are assimilated by soil microorganisms resulting in increased population sizes and activities of microorganisms which in turn influence the transformations of plant nutrient elements in soil. The increased population sizes and activities of microorganisms increased the availability of nutrients in soil.

The influence of Carbofuran on availability of nutrients in sulphate saline (Entisol) and Ultisol soil under rice crop was examined by Jena and Rao (1987). The result showed that the application of insecticide led to increase in available nitrogen as well as phosphorous due to strong proliferation of aerobic non-symbiotic nitrogen fixing bacteria and phosphate solubilizing microorganisms in soil as compared to control.

Gupta *et al.*, (1990) studied the effect of Aldicarb and Carbofuron on nitrification in Inceptisol soil. They reported that available nitrogen in soil increase in the soil treated with Carbofuron While Aldicarb treatment reduced the availability of nitrogen in soil. They stimulation of nitrification by Carbofuron treatment was 4.2 to 23.8 percent over the control while the maximum stimulation occurring on the 5th days of sampling over control treatment.

Das and Mukherjee (1994) conducted a pot culture experiment to study the effect of insecticides (Phorate @ 1.5, Carbofuran (3G) @ 1.0 and Fenvelarate @ 0.35 kg a.i.ha⁻¹) on availability of nutrient under rice crop. They observed that incorporation of insecticides increased the availability of nitrogen, phosphorous due to the greater

stimulation of the activities of phosphate solubilizing/mineralizing microorganisms. The increase was more in case of Phorate as compared to Carbofuron.

Das and Mukherjee (1994a) studied the effect of insecticides Carbofuron (@ 1 kg a.i. ha⁻¹) in flooded *Typic Haplustalf* soil under rice (*Oryza sativa*) crop on the nutrient transformation. The results indicated that amount of available NH₄⁺-N and NO₃-N, DTPA extractable Fe, Mn, Cu and Zn increased with Carbofuron application than with the Ethoprophos (MOCAP 10G) applications as well as over control. At 60 days after, the amount of DTPA-extractable Fe, Mn, Cu, Zn, NH₄⁺-N and NO₃-N increased in soil up to the value of 74.96, 6.96, 9.58, 10.42, 4.58 - 7.24, 0.72 - 0.98 mg kg⁻¹ respectively due to application of Carbofuron and Ethoprophos (MOCAP 10G) application as compared with the corresponding control value i.e. pesticide untreated soil. They further indicated that the magnitude of such increase was more with the application of Carbofuron than with Ethoprophos (MOCAP 10G). The yield of rice was also higher (3800 kg ha⁻¹) with application of Carbofuron compared with Ethoprophos (3460 kg ha⁻¹).

Das and Mukherjee (1998b) conducted a pot culture experiment at the farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia to study the persistence of Phorate and Carbofuran (3G)@ 1.5 and 1.0 kg a.i. ha⁻¹ respectively) in relation to their effect on the Mineralization of N in Alluvial (*Typic Fluvaquent*) Soil. They reported that soil retained higher amounts of NH₄⁺-N than NO₃-N indicating that the process of ammonification was faster than that of nitrification. Between the two insecticides, Phorate released more amounts of mineral N than Carbofuran did. They observed the content of soil exchangeable NH₄-N increased 51.1, 59.2, 55.7, 48.1 and 45.5 ppm at period of 0(lhr), 15, 30, 45 and 60 days after Carbofuron application respectively which is higher than the control i.e. pesticide untreated treatment but lower than the Phorate treated treatment. The soil exchangeable NH₄-N content in Phorate treated sample was found to be 52.5, 61.9, 60.5, 57.8, and 53.8 ppm at period of 0(lhr), 15, 30, 45 and 60 days after Phorate application which is higher than the Carbofuron treated soil as well as pesticide untreated soil treatment. In case of NO₃-N content in soil samples Carbofuron treated soil contains 16.1, 21.5, 24.2, 25.6 and 27.5 ppm at period of 0(lhr), 15, 30, 45 and 60 respectively which is higher than control treatment but lower than the Phorate treated soil. While the NO₃-N content in soil samples in Phorate treated soil contains 18.8, 25.6, 29.6 28.9 and 31.0 ppm at period of 0(lhr), 15, 30, 45

and 60 respectively which is higher than the Carbofuron treated soil as well as pesticide untreated soil treatment. Between the two insecticides, Phorate liberated more amount of available nitrogen as compared to Carbofuran.

Jena *et al.*, (1998) studied effect of insecticides on decomposition of organic matter, ammonification and nitrification in a *Fluventic Ustochrept*. They reported that insecticides application increased the availability of nutrients in soil because insecticides residues and their degradation products are assimilated by soil microorganisms resulting in increased population sizes and activities of microorganisms which in turn influence the transformations of plant nutrient elements.

Das and Mukherjee (2000a, b) and Singh and Prasad (1991) studied the effect of pesticides on N-mineralization. They all found that mineralization of N increased due to the application of insecticides. They reported an increase in the amounts of exchangeable ($\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$) in soil probably due to the stimulation of the growth and activities of ammonifying and nitrifying bacteria which were mainly responsible for mineralization of organic N and convert it into available form.

Madhuri and Rangaswamy (2000) studied the influence of selected insecticides on phosphatase activity in soil (Vertisols) under groundnut crop. They observed that Phosphatase activity significantly increased at 20 days of incubation and decreased progressively with increasing incubation period in Vertisols. Similar results were reported by Rangaswamy and Venkateswarlu (1996).

Madhuri and Rangaswamy (2000), Das and Mukherjee (2000b) and Das and Mukherjee, (1994a) also reported the increase in P availability and higher mineralization of P with the incorporation of insecticides Phorate and Carbofuran suggesting that insecticides significantly increased the phosphate solubilizing/mineralizing microorganisms and availability of phosphorous in soil.

Chen and Edwards (2001) and Chen *et al.*, (2001a) studied the effect of fungicides (Captan, Benomyl, and Chlorothalonil) on N-dynamics in soils of different textured soil. All fungicides enhanced rates of net N mineralization and nitrification initially, but reduced the rates after 20 days.

Hussain *et al.*, (2001a) studied the effect of soil residues of Malathion on nitrogen availability. They reported that nitrogen mineralization is greater in soil

containing residues of Malathion showing a significant increase in $\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$ content in soil as compared to control soil.

Hussain *et al.*, (2001b) studied the impact of heavy repeated long term pesticide application on soil properties under cotton crop. The results indicated that Endosulphon and combination of Profenophos + Cypermethrin inhibited nitrification while combination of Endosulphon + Dimethoate treatment enhanced nitrification as well as $\text{NO}_3\text{-N}$ content in soil over control.

Iqbal *et al.*, (2001) studied the impact of pesticide application (Metamidophos, Monocrotophos, Profenophos+Diefenthionuron, Profenophos+Endosulphon and Chloropyrifos) in under cotton crop. They observed that $\text{NO}_3\text{-N}$ content in soil increased due to application of Profenophos + Diefenthionuron, upto 213.84 ug g^{-1} which is higher than pesticide untreated soil 185.85 ug g^{-1} . While the other pesticide treatments showed negative impacts on soil $\text{NO}_3\text{-N}$ content.

Das *et al.*, (2003) conducted an experiment to investigate the effect of two insecticides (Phorate, Carbofuron @ of 1.5 and 1.0 kg a.i.ha⁻¹ respectively), on the population and distribution of bacteria, actinomycetes and fungi which increases the availability of nutrients as well as the persistence of the insecticidal residues in rhizosphere soils under rice (*Oryza sativa* L., var. IR-20). The study revealed that application of both the insecticides stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils, and they observed stimulation was more pronounced with Phorate as compared to Carbofuran resulting in increased population sizes and activities of microorganisms which in turn influences the transformations of plant nutrient elements in soil and increasing its availability of nitrogen and phosphorous.

Demanou *et al.*, (2004) studied the changes in soil chemical properties due to the fungicide (Ridomil gold plus copper) application. They observed N-(ammonification) and P-mineralization and found higher mineralization of elements, increasing $\text{NH}_4^+\text{-N}$ and available phosphorous by surviving part of the micro flora due to application of Ridomil gold copper fungicide.

Parvaze *et al.*, (2005) conducted a laboratory experiment at Aligarh to study the effect of Phorate (@100, 500 mg a.i. ml⁻¹) on availability of phosphorous using dilution plate method on nutrient agar (NA) medium in combination with PSB

(belonging to genera *Serratia*, *Pseudomonas* and *Bacillus*) and they observed that due to the Phorate treatment there was an increase of 14.2 and 18.8 percent available P content over their respective controls. This may be due to augmentation of the growth and activities of PSB upto a certain limit of dose of Phorate (100 mg ml^{-1}) treatment. This showed that application of Phorate brought about a significant stimulation of growth and activities of PSB which in turn transformed the unavailable form of P into more available form in liquid culture medium. The Phorate treatment above the (100 mg ml^{-1}) decreased the availability of P even in combination with PSB.

Sarnaik *et al.*, (2006) studied the effect of application of pesticides Phorate (30 kg ha^{-1}), Carbofuron (30 kg ha^{-1}), Carbosulphon (30 kg ha^{-1}), Thiomethoxam (3 g kg^{-1}), Imidacloprid (3 g kg^{-1}) and Chloropyriphos (4 ml kg^{-1}) on availability of nitrogen and phosphorous in soil. They observed that availability of phosphorous decreased due to application of all the pesticides with decreasing population count of PSB. While the rhizobial count and available nitrogen increased with the application of some insecticides (Carbofuron, Thiomethexom, and Chloropyriphos) while the decrease in rhizobial count and available nitrogen with the application of some insecticides (Phorate and Carbosulfan).

Srinivas and Raman (2008) conducted a pot culture experiment in red and black soil of Hyderabad to study the effect of Phorate (@ 1.0 and $2.0 \text{ kg a.i. ha}^{-1}$) and phosphorous availability under the cowpea. The results indicated that phorate application (@ 1 kg ha^{-1}) increased the availability of phosphorous as compare to control. But the phorate application at higher rate i.e @ 2 kg ha^{-1} resulted in decreasing the availability of phosphorous as compared to control. The effect of Phorate on phosphatase activity under the cowpea found higher in red soil as compared to black soil.

Bagal (2009) studied the effect of various briquettes on availability of nutrients to rice soils under submerged condition. She reported that application of Phorate briquettes resulted in increasing the availability of potassium as compared to control.

Salam and Subramaniam (2010) conducted an experiment at Tamil Nadu Agricultural University, Coimbatore, India to study the effect of pesticides (no insecticide, Carbofuran @ $0.75 \text{ kg a.i. ha}^{-1}$ and Phorate @ $1.0 \text{ kg a.i. ha}^{-1}$) on availability and uptake of P to IR-20 rice under submerged condition by use of a ^{32}P

absorption technique. They observed that Carbofuran and Phorate application increased availability as well as uptake of phosphorous due to increased root activity. They further reported that effect of Carbofuran was greater than that of Phorate. The enhanced root activity due to application of N and insecticides (Carbofuran and Phorate) increased the uptake of major and micro-nutrients.

Yu *et al.*, (2011) conducted an incubation study to know the effect of pesticides on phosphorous availability in soil. They reported that application of organophosphate pesticides increased the availability of phosphorus while Glyphosate decreased the availability of phosphorous over control.

Singh *et al.*, (2012) examined the influence of Carbofuron application of different rates (0.2, 1.0 and 2.0 kg a.i. ha⁻¹) on availability of nitrogen sandy loam in soils of Aligarh under tomato. The results showed that the increase in available nitrogen up to 1.0 kg a.i. ha⁻¹ Carbofuron application but decrease in availability of nitrogen was observed above 1.0 kg a.i. ha⁻¹ Carbofuron dose.

Vandan *et al.*, (2012) conducted a field experiment at College of Agriculture, ANGRAU, Rajendranagar, Hyderabad, to study the effect of two herbicides (Butachlor @ 1) and Cyhalofop-butyl @ 1kg a.i. ha⁻¹ with nutrient management practices on availability of N and P in clay loam soil under rice crop. The effect of herbicides on availability of N and P in soil was found positive as compared to untreated control due increased in enzyme activity, urease, acid phosphatase and alkaline phosphatase activity. The maximum availability of nutrient attained at 60 days after transplanting.

2.4. Dynamics of primary nutrient fractions in soils:

When fertilizers applied to crop as water soluble source not remain in the soil for longer period and quickly starts getting converted in sparingly soluble or insoluble P compounds due to different soil characteristics. The transformation of added fertilizers greatly depends on physical and chemical environment of soil. Considerable research has been computed on the fate fertilizers for a wider range of crops but few studies have been reported on the availability of primary nutrients to crop in a various soil fertilized at the time of crop growth. The present review is therefore initiated to study the effect of fertilizer and on availability of various inorganic pools of N, P and K.

2.4.1 Dynamics of nitrogen fractions in soils:

Kamat *et al.*, (1982) studied the effect of long-term application of FYM and NPK on organic nitrogen fractions in Vertisol. They reported that small dose of fertilizers with or without FYM raised NO_3 - N level in soil by 2 to 4 times over their initial value.

Prasad *et al.*, (1986) studied the availability of nitrogen forms as influenced by the long term use of fertilizers, lime and manures in an acid soil under multiple cropping. They observed that the exchangeable NO_3 -N, NH_4 -N and available N increased with increasing doses of nitrogenous fertilizers (Urea and diammonium phosphate). The exchangeable NH_4 -N, exchangeable NO_3 and available N increased from 32 to 54, from 5 to 11.5 and from 200 to 368 kg ha⁻¹, respectively with increasing dose of nitrogenous fertilizers.

Sharma *et al.*, (1992) conducted studies on the equilibrium relationship between the inorganic and organic N fractions as affected by application of bioslurry and fertilizer N in a maize-mustard cropping sequence. Application of N fertilized conditions with bioslurry or alone increased NO_3 -N is 13.32 t ha⁻¹. They also reported that magnitude of increase in inorganic N fractions was 15.2 percent over the initial.

Pednekar (1992) conducted an experiment on long range influence of application of manures and fertilizers on the changes in the nitrogen fractions in lateritic soil. He reported that application of nitrogenous fertilizers and organic manures had favorable effect on increasing the content of NH_4 -N. The highest increased NH_4 -N value (5.98 ppm) was reported in the FYM+NPK treatment while the lowest (2.99 ppm) was observed in control and FYM treatments. NH_4 -N content increased in soil in all treatments as compared to its initial status (1.99 ppm). It was further reported that the application of nitrogenous fertilizers in presence of phosphatic fertilizers, potassium fertilizers and organic manures enhanced the content NO_3 -N both over control as well as over addition of nitrogenous fertilizers alone. The highest NO_3 -N value was recorded in the treatment FYM+NPK and the lowest NO_3 -N content (4.32 ppm) was recorded in control. In fallow treatments the content of NO_3 -N was also higher as compared to control, suggesting the depletion in NO_3 -N with cropping. But there was improvement in N fertility even after cropping for nine years, if N was applied either through organic or inorganic fertilizers.

Basumatary and Talukdar (1998) conducted an experiment to monitor the changes in fractions of N in soil as a result of fertilizers dose rice (50, 75 and 100 percent of

RDF dose application). They reported that exchangeable $\text{NH}_4\text{-N}$ and exchangeable $\text{NO}_3\text{-N}$ increased with increase in fertilizer doses at harvest stage of rice over the initial values.

Santhy *et al.*, (1998) studied the N fraction changed due to fertilizer application. They reported that the increase in content of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ at harvest stage was 6.7 and 7.7 ppm respectively than that in initial content of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ was 3.7 and 3.5 ppm respectively due to application of 100 percent RDF NPK fertilizers.

Aruna *et al.*, (1999) studied on the N release pattern of green manure and fertilizers (@ 0, 50, 100, and 150 kg ha⁻¹) with effect on inorganic nitrogen fractions in sandy loam sodic soil of Karaikal. They reported that content of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ at harvest stage increased as N level increased over initial content of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$.

Sharma and Verma, (2001) studied the dynamics of fractions with long term addition of lantana camera biomass and fertilizers in Rice-Wheat cropping sequence in *Typic Hapludalf* soil. They observed that due to hydrolysis and subsequent nitrification of applied urea alone (@ 90 and 120 kg N ha⁻¹) there was an increase of about 25 - 54 percent in $\text{NH}_4\text{-N}$ and 21 - 29 percent in $\text{NO}_3\text{-N}$ at harvest stage at over initial. They reported that the increase in $\text{NH}_4\text{-N}$ at harvest stage was almost double and in $\text{NO}_3\text{-N}$ at harvest stage one and half times when higher levels of N (@ 90 and 120 kg N ha⁻¹) as compared to initial.

Singh and Aulakh (2001) reported that accumulation of $\text{NH}_4\text{-N}$ in submerged soil was more as compared to $\text{NO}_3\text{-N}$ when fertilized, may be due to incomplete inhibition of nitrification in flooded soil because of poor oxygen supply which is more important for nitrification & not necessary for ammonification reaction. As water logging increases O_2 transport decreases and consequently ammonification reaction increases due to its anaerobic nature and nitrification reaction decreases due to its aerobic nature.

Bhattacharya *et al.*, (2006) conducted the experiment to study the nitrogen use efficiency in lowland rice. The results indicates that application of N @ 0, 90 and 120 kg ha⁻¹ alone increases the $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ content in soil at harvest stage as compared to their respective initial content.

2.4.2 Dynamics of phosphorous fractions soil

Goswami and Sahrawat (1982) observed that in neutral to slightly alkaline submerged soils an average increase in P fraction due to fertilizer application to the

extent of 11, 20 and 21 percent in Ca-P, Fe-P and reductant soluble-P respectively over the initial value.

Shinde and Dixit, (1983) studied the transformation of inorganic phosphorous in Alluvial and *Mar* soil of Kanpur under rice crop. They reported that application of P fertilizer (@ 100 and 200 ppm) to soil under submerged condition increased Fe-P, saloid-P, Al-P while Ca-P decreased in comparison to their original values.

Pednekar (1992) conducted an experiment on long range influence of application of manures and fertilizers on the changes in the phosphorus fractions in lateritic soil. He reported that application of phosphorus fertilizers and organic manures had favourable effect on increasing the content of inorganic P fractions in soil at harvest stage over the initial. Application of P fertilizers in combination with manures or alone increased the content of saloid-P, Al-P, Fe-P Ca-P, occluded-P and reductant soluble-P by 185.7, 42.7, 28.5, 117.4, 27.4 and 35.4 percent respectively over control.

Mathan and Joseph (1998) conducted the incubation experiment to study the effect of different fertilizer sources (RP, SSP, DAP and phosphobacteria @ 125 kg ha⁻¹ P₂O₅) on phosphorous dynamics. They reported that increase in Ca-P, Fe-P, Al-P and saloid-P at 90 days ranged between 9.2 - 11.3 , 28.0 - 36.8, 10.3 - 15.6 and 9.4 -12.6 ppm respectively.

Santhy *et al.* (1998) studied the P fraction transformation in *Vertic Ustropept* soil. They observed that increase in saloid-P, Al-P, Fe-P, Ca-P and Olsen-P ranged between 1.0 - 5.7 ppm, 29.2- 78.5 ppm, 26.0 - 36.7 ppm, 169 - 363 ppm, and 2.3 - 7.5 ppm respectively due to the application of 100 percent NPK of RDF over initial values.

Gupta *et al.*, (1999) studied the effect of phosphorous and FYM on changes in phosphorous fractions in Inceptisol soil of Jammu under rice. They reported that application of different P sources with or without FYM treatment increased the content of different inorganic P fractions compared to control. The percent increase over control in Al-P, Fe-P, Ca-P and occluded-P ranged from 9.83 - 110.61, 2.55 - 26.20, 1.43 - 44.88 and 0.57 - 13.75 respectively.

Tamboli and Daftardar (2003) studied the effect of phosphorous on inorganic P fractions in greenhouse experiment having Vertisol Rahuri (*Nimone series*) and Alfisol (*Wakawali series*) soils. They reported that application of inorganic fertilizers to crop increased Ca-P , Fe-P, Al-P, reductant soluble-P and saloid-P in *Nimone series* at

harvest stage which ranged between 239.5 - 408.9, 5.17 - 27.6, 20.04 - 60.67, 18.80 - 49.04 and 11.52 - 23.97 ppm respectively, while in *Wakawali series* soil increased in Ca-P, Fe-P, Al-P, RS-P and saloid-P at harvest stage ranging between 10.6 - 52.67, 29.3 - 114.6, 20.04 - 65.67, 11.80 - 50.54 and 7.29 - 15.97 ppm respectively.

Abunyewa *et al.*, (2004) studied the transformation of phosphatic fertilizer in Vertisol soils of Coastal Savanna Zone of Ghana under maize crop. They reported that increase in Available-P, Ca-P, Al-P and Fe-P ranged from 3.0 - 4.73, 23.5 - 29.0, 5.1 - 5.49 and 0.24 - 0.31 ppm due to fertilizer application (@ 0, 50 and 100 percent of the rate of recommended fertilizer dose) to maize crop over the initial values.

Laxminarayan and Ramgopal (2004) studied the effect of submergence on P dynamics in soils of Andhra Pradesh under rice crop in order to determine the critical level of available P so as to adjust the fertilizer P recommendations. From the study it was observed that the submergence of soils increased the available P status due to an increase in Fe-P, occluded-P and Ca-P. They reported that increase in Fe-P, Al-P, Ca-P, saloid-P, reductant soluble-P from 33.4 - 40.1, 38.9 - 39.0, 78.9 - 87.2, 4.5 - 4.6 and 27.4 - 33.1 ppm respectively due to fertilizer application as well as due to submergence over control.

Chitdeshwari and Savithri (2005) conducted the greenhouse experiment in an Inceptisol soil of Coimbatore, Tamilnadu under submerged rice to study the effect of different sources of P fertilizers (bone meal, Superphosphate and their mixtures). They reported that among the various P fractions 50-60 per cent of applied P was converted into Ca-P, followed by the Fe-P, Al-P and saloid-P. The entry of applied P followed the order Ca-P > Fe-P > Al-P and saloid-P. They reported that increase the inorganic P fractions viz. saloid-P Al-P, Fe-P, and Ca-P of ranged between 11.7 - 12.80, 15.1 - 22.2, 17.2 - 49.6 and 54.3 - 85.6 ppm over the initial value as well as control treatment.

Chesti and Ali (2007) studied the effect of graded dose of phosphorous on transformation of phosphorous fractions. The results revealed that application of P @60 kg P₂O₅ ha⁻¹ increased the Fe-P, Al-P and Ca-P from 12.46 - 16.01, 19.88 - 26.77 and 40.50 - 54.77 ppm respectively. The amount of P recovered in Al-P, Fe-P and Ca-P forms increase significantly with the application of inorganic P fertilizers and biofertilizers material over control. Among the all treatments, inorganic- P (Al-P, Fe-P and Ca-P) forms gave the highest value with biofertilizers treatments due to higher

activity of micro-organisms in soil. Among the biofertilizers inoculants, *Pseudomonas* gave highest value of inorganic P fractions over *Bacillus*.

Mujumdar *et al.*, (2007) studied the effect of rock phosphate, superphosphate and their mixtures with FYM on soil-P pool in *Typic Hapludalf* (Alfisol) soils of Meghalaya under Soybean. They reported that applied phosphorous with or without FYM with different sources (SSP, RP and SSP+RP) increase the inorganic P fractions viz. saloid-P Al-P, Fe-P, and Ca-P ranged between 1.7 - 9.00, 47.0 - 63.12, 45.0 - 63.00 and 3.3 - 9.0 ppm over the initial value as well as control treatment.

Kumar *et al.* (2009) studied the influence of long term application of farm yard manure and inorganic fertilizers on N on the soil P fractions in *Typic Ustochrept* soil of Hisar India. They reported that levels of P fertilizer 30, 60, 120 kg ha⁻¹ increased the saloid-P, Al-P, Fe-P, Ca-P and reductant soluble - P content of the soil at harvest stage up to 14.46, 42.23, 227, and 30.68 mg kg⁻¹ respectively over the initial i.e. saloid-P, Al-P, Fe-P, Ca-P and reductant soluble-P content of the soil 2.93, 19.33, 29.29, 203 and 21.26 mg kg⁻¹ respectively.

Sharma *et al.*, (2009) studied the effect of long term lantana camera addition on soil phosphorous fractions and their relationship with crop yield and P uptake in Rice-Wheat cropping in North-West Himalayan acid Alfisol soil. They reported that application of 100 per cent recommended dose of fertilizers increased all the inorganic fractions of P at harvest stage i.e, NaHCO₃-P increased from 10.31 to 13.70 ppm, NaOH-P increased from 135.18 to 137.34 ppm, HCl-P increased from 203.45 to 226.73 ppm, residual-P increased from 203.45 to 226.73 ppm and total P increased from 481.21 to 586.60ppm.

Jun *et al.*, (2010) studied inorganic phosphorus fractions and phosphorus availability in a calcareous soil receiving superphosphate application. They observed that soil inorganic phosphorous content increased from 421.5 - 737.6 mg kg⁻¹. They reported that soil inorganic phosphorous content increased by 19.7, 16.4, 64.6 and 75.0 percent when fertilizer P rates were 20, 39, 59 and 79 kg P ha⁻¹, respectively as compared with no fertilizer P application.

Singh *et al.*, (2010) studied the effect of long term fertilizer use on soil phosphorous (inorganic fraction.). Their results showed that use of P fertilizer @ 100:

22: 41 kg ha⁻¹ NPK dose increases the saloid-P from 3.5 - 7.6 ppm. Al-P from 56.6 - 90.7 ppm, Fe-P from 4.8 - 6.4 ppm and Ca-P increased from 329 - 415 ppm.

Hemalatha and Chellamuthu (2011) studied the effect of long term fertilization on phosphorous fractions under finger Millet-Maize cropping sequence in *Vertic Ustropept* soil of Coimbatore. They observed that all the P fractions increased with increasing levels of fertilizer doses and were higher under continuous application of 150 per cent NPK followed by 100 per cent NPK + FYM. Among all the fractions Ca-P dominated the rest of the fractions. They reported that saloid-P, Al-P, Fe-P, Rs-P and Ca-P increased due to fertilizers applications within the range of 10.79 - 26.21 ppm, 18.88 - 50.24, 14.97 - 31.45 ppm, 12.40 - 31.26 ppm and 91.57 - 257.93 ppm over initial respectively.

Abolfazli *et al.*, (2012) studied the effect of P fertilizers (@ 10, 20 and 30 mg kg⁻¹) on phosphorus fractions in submerged soil. Results of this study showed that all forms of P under submerged conditions had been increased because of application of P Fertilizers alone or in combination with organic fertilizers. The increased percentages were in case of reductant soluble-P increased from 9.8 to 27.5 percent, Ca-P increased 12 to 13 percent over their initial value.

2.4.3 Dynamics of potassium fractions in soils:

Prasad and Rokima (1991) studied the transformation and availability of applied potassium fertilizer (@ 0, 50, 75 and 100 percent of recommended NPK dose in combination with organic manure and BGA) into various fractions in Calciorthant soil. It was found that added K was transformed into water soluble K 0.06 - 0.12 of the percent total K, Non-exchangeable-K 5.2 - 7.0 percent of the total K and exchangeable-K 0.76 - 0.98 percent of the total K which results in to increase in these fractions over initial value.

Pednekar (1992) conducted an experiment on long range influence of application of manures and fertilizers on the changes in the potassium fractions in lateritic soil. He reported that application of potassium fertilizers alone or in combination with organic manures had favorable effect on increasing the content of potassium fractions in soil at harvest stage over the initial. Application of K fertilizer in combination with manures or alone increased the content of water soluble K,

exchangeable - K, non-exchangeable-K by 60.7, 27.7, and 28.5 percent respectively over control.

Prasad (1992) studied the fate of applied K fertilizer in calcareous soil under different cropping system. He reported that under rice-wheat cropping system increase in water soluble-K, exchangeable-K and non exchangeable-K at harvest stage over the initial value due to the fertilizer application.

Srivastava and Srivastava (1992) conducted a pot culture experiment in *Typic Natraqualf* soils of Varanasi under rice crop to study the relationship between K forms. All pots received RDF 60:30:30 ppm NPK with and without various soil amendments (gypsum and pyrite). They reported that increase of water soluble K, exchangeable K, and non-exchangeable-K from 19.5 - 37.1 ppm, 53.1 - 120.1 ppm and 1562.2 - 1780.6 ppm respectively which is higher than absolute control treatment as well as initial values.

Talele *et al.*, (1993) conducted an incubation experiment to study the effect of added K on transformation of available-K and non exchangeable-K in different soils of Maharashtra. They reported that increase in $\text{CaCl}_2\text{-K}$ on incubation for 30 days in Entisol (Panvel), Oxisol (Radhanagari), Inceptisol (Paud), Vertisol and Alfisol was 2.9 - 26.8, 35.3 -39.3, 17.2 - 22.6 , 19.9 - 18.5 and 18.7 - 37.3 percent respectively due to K fertilization @ 1 cmol. kg^{-1} soil and 2 cmol. kg^{-1} soil over the control. They reported that increased in exchangeable potassium of Entisol (Panvel), Oxisol (Radhanagari), Inceptisol (Paud), Vertisol and Alfisol in 30 day due to application of K fertilizer @ 1 and 2 cmol kg^{-1} was 4.1 -11.0 , 28.9 - 30.3 , 6.1 - 22.6 , 3.8 - 34.1 and 7.4 - 30.4 percent respectively over control. They reported that increase in non exchangeable-K in 30 days of incubation in Entisol (Panvel), Oxisol (Radhanagari) Inceptisol (Poud), Vertisol and Alfisol was found in the range of 61 - 95, 37 - 46, 55 - 79, 75 – 87 and 47 - 82 percent respectively, over the control due to application of K fertilizer @ 1 and 2 cmol kg^{-1} .

Jadav *et al.*, (1993) studied the effect of fertilizer application (@ 0, 30, 60 and 90 ppm) with or without lime on K transformation in incubated *Vertic Ustropept* soils of Gujarat. They reported that increased in water soluble-K, $\text{HNO}_3\text{-K}$ and available-K at 90 days after incubation from 15.2 - 43.00 ppm, 45 - 361 ppm, and 16 - 163 ppm, respectively over the initial value due to the application of various potassium doses.

Singh and Jha (1994) conducted an experiment in Calciorthant soil under sugarcane to monitor the changes in fractions of K as a results of fertilizers dose (0, 50, 100 and 150 K₂O kg ha⁻¹) application. They reported that added potassium was transformed upto harvest stage into non-exchangeable-K ranging between 412 - 491 ppm form followed by water soluble-K 8 - 10 ppm and exchangeable-K 46 – 58 ppm which shows higher values than control as well as initial.

Basumatary and Talukdar (1998) conducted an experiment under rice crop to monitor the changes in fractions of K in soil due to application of fertilizer doses (50, 75 and 100percent of RDF dose) application. They reported that water soluble-K, HNO₃-K and available-K increased with increase in potassium doses at harvest stage of rice over the initial values.

Santhy *et al.*, (1998) studied the effect of fertilizer application on K transformation in *Vertic Ustropept* soils of Tamilnadu. They reported that increased in water soluble-K, exchangeable-K, non exchangeable -K, total-K and available-K from 12 - 24 ppm, 183 - 244 ppm, 813 - 1036 ppm, 3665 - 3939 ppm and 198 - 273 ppm respectively over the initial value due to the application of 100 percent of NPK RDF dose .

Singh *et al.*, (2000a) studied the different forms of K in soil in Vertisol. They reported that water soluble-K, HNO₃-K and Available-K increased with increase in potassium doses upto 80 kg ha⁻¹ at harvest stage over the initial values.

Thippeswamy *et al.*, (2000) potassium transformation studies in lowland rice Alfisol soil as influenced by levels and time of K application. They reported that water soluble-K, HNO₃-K and Available-K increased with increase in potassium doses upto 80 kg ha⁻¹ at harvest stage over the initial values.

Setia and Sharma (2004) studied the effect of fertilizer application on changes in K form. They reported that at harvest stage the inorganic K fraction changes as water soluble-K increased from 11 - 14.4 ppm, exchangeable-K increased from 49.0 - 56.4 ppm, non-exchangeable-K increased from 623 - 656 ppm and total k increased from 9125 - 9875 ppm due to fertilizer applied @ 120:40:40 kg ha⁻¹ NPK over initial value.

Dhar *et al.*, (2009) conducted an experiment to assess the changes in different pools of soil K under rice cropping in Alfisol soils of West Bengal into successive year. They reported that increase in exchangeable - K pool of soil 49 percent after harvest of

rice crop as compared to its initial status when K fertilizer applied as per the recommended dose of rice.

2.5 Pesticides Residues in soil and plant.

The fate of soil applied insecticides depends on three important processes like adsorption, degradation and uptake by crop. All these three processes depend upon physico-chemical properties of soil as well as shape, solubility and rate of application of pesticides. Pesticides residue may remain in the growing plant, surface soil as well as deeper layers of the soil for long time, even for years as a contaminant. Considerable research has been computed on the fate pesticides for a wider range of crops but few studies have been reported on the residue content of pesticides in different soil at the time of crop growth. It was considered worthwhile to evaluate the effect soil characteristics on the persistence of pesticides in soil as well their toxicity to crops the available research reviews is been discussed below.

2.5.1. Pesticides Residues content in soil:

The importance of clay type on pesticides residues content was reported by Yaron (1978). He conducted a laboratory experiment to examine the surface interaction of clay by organo phosphorus pesticides. He used the various type of clay for the 40 days incubation study with Parathion and observed that amount of parathion residues contained in various types of Smectite clay ranged between 3.5 - 15.5 percent while only 0.5 percent of applied pesticide was adsorbed on the Kaolinitic clay. He further concluded that residues content of pesticides increased with increasing swelling capacity of clay because of swelling type (Smectite) clay. Pesticides residues get absorbed in Smectite type of clay structure in higher amount whereas the pesticides residues get adsorbed on the Kaolinite type.

Keiger and Yaron (1975) studied the recovery of Parathion added to 14 soils of varying texture, clay mineral type, and percent organic matter (OM). They concluded that Parathion fixation by soil was a function of soil organic matter and amount and type of clay minerals. Soils which contain Smectite clay retain Parathion much more strongly than kaolinitic clays. Parathion also is more strongly sorbed by organic matter than by clay.

Walter-Echols and Lichtenstein (1978) studied the fate of Phorate in Plano loam soil under flooded conditions and non flooded conditions. The conclusions were that Phorate residues content in soil was more in flooded soils than in non flooded soils.

Chapman *et al.*, (1982) studied on the residues of Phorate in minerals and organic soils. They concluded that Phorate disappeared much more rapidly from nonsterilized than from sterilized soils. In 16 weeks, pesticides tested (Phorate) were at zero concentration in the natural soils, while significant quantities were still present in the sterilized soils.

Nelson *et al.*, (1982) studied on the effect of pesticides on nutrient availability in soil. They concluded that application of organophosphorus pesticide increase the availability of nutrients due to pesticide at 4 to 5 days after application due to increase in population of bacteria in soil. They found that when adding labeled parathion (^{14}C label in the alkyl chain of the compounds) to soil, the soil bacterial population rapidly increased to a maximum population in 4 to 5 days by 40 - 50 percent over the initial.

Naragund *et al.*, (1985) studied the movement of Parathion in soils of Karnataka. They reported that the residue content of Parathion was found to be limited at upper three inches of soil due to limited movement of pesticides in soil having higher CEC as well as higher clay content.

Waliullah (1985) conducted an experiment in soils of IARI Delhi under rice crop. The Carbofuron was applied to soil @ 2 kg a.i.ha^{-1} at the time of transplanting of rice. The Carbofuron residues in soil was found to be 4.94, 0.22 ug g^{-1} at 30 and 75 days after application respectively.

Valliappan (1987) conducted a field study at Agricultural College and Research Institute, Madurai, India to estimate the residues of Carbofuran, Phorate and Butachlor in soil under rice (IR 20). For this study the application of the pesticide doses to soil were Carbofuran ($0.5, 1.0, 1.5 \text{ kg a.i.ha}^{-1}$), Phorate ($1.0, 2.0 \text{ and } 3.0 \text{ kg a.i.ha}^{-1}$) and Butachlor ($1.0, 2.0 \text{ and } 3.0 \text{ kg a.i.ha}^{-1}$). The residue of Carbofuron in soil at harvest stage was found to be 0.0431, 0.0746 and 0.0920 ppm where Carbofuron applied at rate 0.5, 1.0 and $1.5 \text{ kg a.i.ha}^{-1}$ respectively. They reported the residues of Phorate in soil at harvest stage as 0.0346, 0.0426 and 0.0770 ppm when application of Phorate was 1.0, 2.0 and $3.0 \text{ kg a.i.ha}^{-1}$ respectively. The residue of Butachlor in soil at harvest stage was found to be 0.0120, 0.0178 and 0.0246 ppm when the application rate was 1.0, 2.0 and

3.0 kg a.i.ha⁻¹ respectively. From this study it was also concluded that the residue content of pesticides in soil decreased as dose of application decreased to soil.

The residue content of pesticide in soil varied with type of soil as reported by Reddar *et al.* (1988) who conducted a greenhouse experiment in lateritic, black and red soil of Karnataka under rice crop to estimate the residue content of Carbofuron in soil. They observed the Carbofuron residues in soil at 40 days after application which ranged between 42 - 86 ug, 56 - 95 ug and 56 - 90 ug in black, lateritic, and red soil respectively.

Gupta *et al.*, (1989) conducted an incubation experiment in Inceptisol soil to estimate the residues of Phorate in soil. At 40th day of incubation the Phorate residues in soil were found to be 4.56 ppm.

Mukherjee *et al.*, (1990) studied the residue of Carbofuron and its translocation in soil under soybean crop. They observed that the residue content in soil just after the application was found higher (2.18 ppm) which declined (1.10 ppm) as time of application elapsed (at 30 days). While the residue of Carbofuron in soil on 70th days was found decrease upto 0.16 ppm and was negligible (0.01 ppm) at the 110th day.

Mehta and Narayanswamy (1993) studied the effect of Phorate applied at different rate (4, 3 and 2 kg a.i. ha⁻¹) in sugarcane ecosystem at Coimbatore India. The result indicate that phorate application at the recommended dose (2 kg a.i. ha⁻¹) being an effective Nematicide with no residual toxicity in soil and sugarcane above toxic limit. They reported that at 65 days the residues of Phorate in soil ranged between 0.0398 - 0.02 ppm at all the level of application.

Two laboratory experiments were conducted by Sundaram (1994) in soils of Newzeland. First experiment includes the study on the effect of different sources added carbon (peat, slugde, mushroom compost, pig manure) and dissolved organic carbon addition on residue content of pesticides in soil. He observed that pesticide residues content in soil increased with increasing organic carbon and clay content in soil while the pesticides residue content pattern in soil among the all carbon sources were found followed in the order peat > sludge > pig manure > mushroom compost > poultry manure. Second experiment was also conducted by Sundaram (1994) with using simulated cores of two different soils which repacked in column to study the sorption and movement of pesticides within soil profile. They reported that soil having high

infiltration rate contain less amount of pesticides residues in soil at all the depths than soil having lower infiltration rate. They also showed that less amount of pesticides residues reached at lower depth due to fewer micropores. Among the pesticides used for the experiments followed the residue contain pattern Terbufos > Phorate > 2-4-D > Atrazine > Metsulfuron methyl in both the soils.

An incubation study was conducted by Karpouzas *et al.*, (2001) using the VARLEACH model. The surface soil i.e. top-soil and subsurface soil i.e. sub-soil samples of one of the profile treated with Carbofuran (@concentrations from 0.1 to 10 mg kg⁻¹) for 12 months in simulated condition. They reported that Carbofuran residues (0.01 mg kg⁻¹) reached upto a depth of 70 cm through the soil profile.

Behki, and Khan (2001) conducted the column lysimeter experiment in a sandy loam and loam soil under the corn field to evaluate the residues of pesticides in soil. The commonly used pesticides to corn, Atrazine and Carbofuran in combination and alone was applied (@ 2.93 a.i. ha⁻¹) to column which fitted into field. Three years pooled analyzed data of soil samples showed that 37 percent of the applied Atrazine and 32 percent Carbofuran was present in the soil as residue at the end of two months after application. They further reported that among the two pesticides Carbofuran degraded and dissipate at faster rate in soil than Atrazine.

Senapati and Padhihari (2002) studied the effect of organic, inorganic fertilizers and liming on residues of Phorate in acid Lateritic soils of Orissa. They showed that residue content of Phorate (0.39 - 0.82 ppm) in soil found less in fertilized soil at 30 days after application (@ 1, 2 kg a.i. ha⁻¹) which is less than control (0.092 ppm) i.e, unfertilized soil. Whereas the content of residue of pesticide in soil at 30 days after application in all the treatments followed a pattern: lime (0.039 ppm) < FYM < (0.057 ppm) < phosphorous (0.059 ppm) potassium < (0.069 ppm) nitrogen (0.082 ppm) < control (0.092 ppm). This data concluded that application of organic, inorganic fertilizers and liming to soil helps to decrease the residue of pesticides in soil.

Das *et al.*, (2003) conducted an experiment to investigate the effect of two insecticides (Phorate @ 1.5 and Carbofuron @1.0 kg a.i.ha⁻¹), on the persistence of the insecticidal residue in rhizosphere of soil under rice (*Oryza sativa L.*, var.IR-50). They reported that residue of Phorate and Carbofuron in rice *Rhizosphere* soil at 30th day

after application of pesticides was 0.07 ppm and 0.04 ppm respectively while it was found a negligible at 90th day after application.

Tariq *et al.*, (2006) conducted a laboratory incubation lysimeter experiment to evaluate the influence of temperature, moisture, and microbial activity on degradation and persistence of cotton pesticides (Carbosulfan, Carbofuran, λ -Cyhalothrin, Endosulfan, and Monocrotophos) in sandy loam soils (*Typic Ustocurepts*) from Punjab. They observed the presence of Carbofuran and Monocrotophos in the soil profile (0-10, 10-30, 30-60, 60-90 and 90-150 cm) and the higher concentrations of Endosulfan and λ -cyhalothrin in the top layer (0-10 and 10-30 cm). The detection of Endosulfan and λ -Cyhalothrin in the 10-30 cm soil layer might be due to preferential flow.

Ruggieri *et al.*, (2008) conducted a laboratory multi-lysimeter experiment in the loam soil of the Fucino Plain (Italy) to investigate the mobility and persistence of pesticides (Simazine, Carbaryl, Dicloran, Linuron and Procymidone under simulating conditions. They estimated the pesticide residue in the soil columns as a function of time (60 days) from application and depth (40 cm). They observed that at the end of about 60 days the pesticides residue were observed at only on the surface layer and no residue was detected at depths greater than 20-30 cm.

Farahani *et al.*, (2008) conducted the column study for 14 days having disturbed and undisturbed soil profile to study the downward movement of Carbofuran in two Malaysian soils (clayey soil from Bagan Datoh and the sandy clay soil from Labu). They observed that more residues were accumulated at the top layers of the soil column. It is interesting to note that the mobility of Carbofuran was higher in undisturbed soil columns than in disturbed soil columns. Approximately 3.6 - 3.1 percent of Carbofuran was found as a residues in the 25-30 cm soil layer of undisturbed soil containing column while only 2.0 - 1.6 percent Carbofuran was found in the 25-30 cm soil layer of disturbed soil containing column. However, on the other hand, it was observed that the residue of Carbofuran decreased with increasing depth of the disturbed and undisturbed soils.

Krishna and Philip (2008) studied the adsorption and desorption characteristics of three insecticides (lindane and Methyl parathion and Carbofuran) on four Indian soils (compost soil, clayey soil, red soil and sandy soil). They reported the order of content of residues of pesticides in soils was: Lindane > Methyl parathion > Carbofuran

while order of residues content and adsorption capacity of various soils were: compost soil > clayey soil > red soil > sandy soil. These results indicated that residues content of pesticides in soil decreased with increasing infiltration rate as well as sand percent in soils.

Pany *et al.*, (2008) conducted an experiment in soil of Orissa Bhubaneswar under rice to study the persistence of Phorate with the various rate of application (@ 1, 1.5 and 3 kg a.i.ha⁻¹). They observed Phorate residues in soil after 15 days of Phorate application as 0.95, 1.41 and 2.25 ppm at the application @ 1, 1.5 and 3 kg a.i.ha⁻¹ respectively. They reported that at 60 DAA Phorate residues was not detected in soil at any of the level of Phorate application.

Sridevi *et al.*, (2008) conducted a green house experiment of 25 days to evaluate the persistence of Phorate 10 G in different types of soil viz red sandy loam, black sandy loam, clay and alkaline sandy clay loam soil under paddy crop. The residues of Phorate in soil at 25th day was found highest (0.361 ppm) in alkaline sandy clay loam soil while the lower residues 0.257, 0.224 and 0.245 ppm were found in red sandy loam, black sandy loam and clayey soil respectively.

Benicha *et al.*, (2011) conducted an incubation experiment in clay loam soil from Loukkos perimeter, Northwestern Morocco under flooded and moist condition, to study on residue of Carbofuran in soil. They reported that, residues of Carbofuran were higher in flood soil compared to moist soil conditions. At the end of 63rd day of incubation 29.1 percent of Carbofuran applied was found as residue in soil while same was observed 33.3 percent under flooded soil condition.

Mohamed *et al.*, (2013) studied the dissipation processes of Carbofuran in clayey soil of Loukkos area Northwest Morocco under sugar beet as influenced by soil water content, sterilization. They observed that Carbofuran residues in autoclaved soil reached 19 percent at 63rd days of incubation vs. 32 percent in non-autoclaved soil. This means that Carbofuran disappearance rate was 3.5 times lower under sterile conditions as compared to that under natural soil condition. They also reported that disappearance rate of Carbofuran decreased with increasing soil water content i.e. Carbofuran residue in soil at 63rd day was more than 23 percent at 100 percent WHC, while it was 20.3 and 8.3 percent at 60 percent and 20 percent WHC, respectively. They obtained

48.64 and 23.08 percent as residues of Carbofuran respectively under moist and flooded conditions over a period of 30 days.

2.5.2 Pesticide residues content in plant:

Seiber *et al.*, (1978) studied on the pesticide residue content in rice crop as affected by Carbofuran application rate and method of application as a systemic insecticide under irrigated wetland condition. They found that residues of Carbofuran in rice plants did not exceed the 0.2 ppm from fields treated by soil incorporation and root-zone placement. While the Carbofuran residues in whole grain did not go above 0.2 ppm in the plants that received six broadcast application of Carbofuran at fourteen-day intervals throughout the growing season which is less than tolerance allowed in whole grains given by the United States Environmental Protection Agency standards.

Garg and Sethi (1982) studied the residue content of pesticides in different parts of rice at New Delhi. They reported that after 60 days of transplanting, Phorate residues in root, stems, leaves, ear head and grains were found to be 3.34, 4.60, 4.82, 1.83 and 0.25 ppm respectively where Phorate application rate to rice crop was @ 2.0 kg a.i.ha⁻¹.

Waliullah (1985) conducted an experiment in soils of IARI Delhi under rice crop to examine the residues of Carbofuran in rice plant at various period of rice growth when the rate of application of Carbofuran was @ 2 kg a.i. ha⁻¹. It was revealed that Carbofuran residues in rice plant at 30th and 75th days after applications of Carbofuran were 33.4 and 10.0 ug g⁻¹ respectively.

Meher *et al.*, (1985) studied residues of Carbofuran in pea plant parts where the rate of application was @ 0.5 kg a.i. ha⁻¹. Carbofuran residues in pea root, shoot and pod at 75 days after application of Carbofuran were 0.18 ug g⁻¹, 0.05 ug g⁻¹ and 0.06 ug g⁻¹ respectively.

Sundararaj (1985) studied the effect of Carbofuran concentration in grain and straw of rice as affected by different Carbofuran doses. They reported Carbofuran residues in grain at harvest stage were found to be 0.041, 0.054 and 0.069 ppm at 0.50, 0.75 and 1.00 kg a.i. ha⁻¹ at the application rate while in straw it was found to be 0.033, 0.048 and 0.054 ppm when at the application rate 0.50, 0.75 and 1.00 kg a.i. ha⁻¹, which is less than tolerance limits of 0.2 ppm fixed by WHO and USEPA. They concluded that residues in all parts increased with increasing rate of application.

Valliappan (1987) conducted a field study at soils of Agricultural College and Research Institute, Madurai, India under rice crop to estimate the residues of Carbofuran, Phorate and Butachlor in soil as well as in rice (IR-20) following the various rate of application of the pesticides. They reported that residues of Carbofuran in grain at harvest stage was found to be 0.0346, 0.0620 and 0.0700 ppm at 0.5, 1.0 and 1.5 kg a.i.ha⁻¹ Carbofuran application respectively and the residue of Phorate in grain at harvest stage was found to be 0.0240, 0.0310, and 0.0420 ppm at application rate of Phorate 1.0, 2.0 and 3.0 kg a.i. ha⁻¹ respectively. Further they reported that residues of Butachlor in grain at harvest stage as 0.0046, 0.0310, 0.0420 ppm at application rate 1.0, 2.0 and 3.0 kg a.i.ha⁻¹) respectively.

Valliappan (1987) conducted a field study in soil of Agricultural College and Research Institute, Madurai, India under rice to estimate the residues of Carbofuran, Phorate and Butachlor in soil as well as in rice (*Var-IR 20*) following the application of the various dose of pesticides. It is revealed that residues of Carbofuran in straw at harvest stage as 0.0106, 0.0127, and 0.0137 ppm when Carbofuran was applied @ 0.5, 1.0 and 1.5 kg a.i.ha⁻¹) respectively. They reported that a residue of Phorate in straw at harvest stage was found to be 0.0100, 0.0102 and 0.0112 ppm when Phorate was applied @ 1.0, 2.0 and 3.0 kg a.i. ha⁻¹ respectively. The residue of Butachlore in straw at harvest stage was reported as 0.0740, 0.0800 and 0.0880 ppm at application rate of 1.0, 2.0 and 3.0 kg a.i.ha⁻¹ respectively.

Reddar *et al.*, (1988) conducted a greenhouse experiment in lateritic, black and red soil of Karnataka under rice crop to know the persistence of Carbofuran in rice plant. They observed the Carbofuran residues in rice plant leaf at 40 days after application ranged between 95-130 ug g⁻¹, 100 - 135 ug g⁻¹ and 90 - 145ug g⁻¹ in black, lateritic, and red soil respectively.

Singh *et al.*, (1994a) resulted that residue concentrations of Phorate in plant increased with increasing level of nitrogen application rates. The residues of Phorate at maturity phase in sugarcane crop were in the range of 0.16 - 0.4 ppm which is lower than the toxicity level given by FAO/WHO.

Kumar *et al.*, (2006) studied the residue content of Carbofuran in rice at the application rate @10g/4m² to rice and they found that maximum residue content in rice straws and in grain 0.071 ppm and 0.0016 - 0.041 ppm respectively. The residue of

Carbofuron was detected below maximum residue limit of 0.1 ppm in grain after harvest.

Pany *et al.* (2008) conducted an experiment at rice field of Orissa Bhubaneswar with the various rate of Phorate application (@ 1, 1.5 and 3 kg a.i. ha⁻¹) to study the persistence of Phorate in plant. They observed that average Phorate residue on third day in rice plant leaf was 0.40, 0.54 and 0.85 ppm at (@ 1, 1.5 and 3 kg a.i.ha⁻¹ Phorate doses respectively. Thereafter at 7th day Phorate residue in rice plant leaf increased up to 0.45, 0.65 and 1.05 ppm @ 1, 1.5 and 3 kg a.i.ha⁻¹ Phorate doses respectively while at 45th days of plant sampling the average Phorate residues in rice plant leaf was 0.03, 0.07 and 0.12 ppm at @ 1, 1.5 and 3 kg a.i. ha⁻¹ Phorate application dose, and at the harvest stage the plant sample as well as grain sample from the experiment didn't show any toxic level of residues irrespective of the dose Phorate applied.

CHAPTER IV

RESULTS AND DISCUSSION

In the present investigation an attempt has been made to study the “movement behaviour of primary nutrients, carbamates and organophosphate based insecticides in different soil matrices” under the effect of combinations of chemical fertilizers with pesticides in Lateritic, Medium black, and Coastal saline soils of *Konkan* during *Kharif*, 2012-13 and 2013-2014 of rice hybrid (Sahyadri-4). The effect of different treatments on content, uptake of primary nutrients by rice crop in different soil types and the changes in primary nutrient availability in different soil types under rice crop as affected by pesticides application at their recommended dose were studied. The leaching losses of primary nutrients and pesticide from different soil types under rice crop were also examined. The leaching losses of pesticides as well as their movement and distribution in profile of different soil types using soil column were carried out. The residues content of different pesticides in rice grain, straw and soil was analyzed.

The observations and analytical values obtained during the course of study were analysed statistically, described and contemplated to discuss the variations observed with an attempt to establish the ‘effect and cause’ relationship in the light of available evidences and literature. The results and discussion has been divided into the following heads:

A. Experiment-I

- 4.1 Physico-chemical properties of soils and its profile.
- 4.2 Leaching losses of primary nutrients and pesticides at different growth stages of rice crop as affected by various treatments.
- 4.3 Effect of different treatments on growth and yield of rice.
- 4.4 Effect of different treatments on content and total uptake of primary nutrients (N, P, K) by rice.
- 4.5 Effect of different treatments on content pesticides by grain and straw of rice.
- 4.6 Effect of different treatments on availability of primary nutrients (N, P and K) and pesticides residues in soil at different growth stages of rice crop.
- 4.7 Effect of different treatments on forms of primary nutrient (N, P and K) in soil at harvest stage of rice.

- 4.8 Correlation between various physico-chemical properties with available macronutrient and pesticides at different growth stages of rice.

B. Experiment-II

- 4.9 . Effect of soil types on pesticides leaching losses and their movement in soil profile at different depth.

4.1. Physico-chemical properties of soils and its profile.

The soil samples were collected from Dapoli, Karjat and Panvel representing Lateritic, Medium Black and Coastal saline soil types respectively. Various physical properties of these soil like mechanical composition (percent sand, silt and clay), bulk density, infiltration rate, porosity and the chemical properties like pH, electrical conductivity, organic carbon, available N, available P_2O_5 , available K_2O , various forms of primary nutrients, cation exchange capacity, DTPA- extractable Fe, Mn, Zn, and Cu have been determined at various soil depths viz. 0-30, 30-60 and 60-90 cm the results obtained are presented below.

4.1.1 Physical properties of soils:

The physical property determined are presented in Table 9. All the three soil types under studies were analysed at three different depths for various soil physical properties like mechanical composition %, bulk density, porosity, infiltration rate.

Table 9 : Physical properties of different types of soil profiles studied.

Soil depth cm	Mechanical Composition (%)			Textural class	Bulk density Mg m ⁻³	Porosity %	IR cm hr ⁻¹
	Sand	Silt	Clay				
Lateritic soil - Location Dapoli							
0-30	59.52	14.72	25.76	Sandy clay loam	1.25	38.10	2.1
30-60	37.00	28.00	35.00	Clay loam	1.28	35.40	
60-90	32.52	36.00	31.48	Clay loam	1.28	35.30	
Medium black soil - Location Karjat							
0-30	39.88	24.36	35.76	Clay loam	1.27	28.65	1.4
30-60	38.96	22.00	39.04	Clay loam	1.29	22.62	
60-90	42.96	24.00	33.04	Clay loam	1.22	25.62	
Coastal saline soil - Location Panvel							
0-30	33.04	20.48	46.48	Clay	1.29	20.60	0.9
30-60	40.96	28.00	31.04	Clay loam	1.24	22.35	

60-90	44.96	30.00	25.04	Loam	1.20	25.60	
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4.1.1.1 Mechanical composition:

The data on mechanical composition of soil profile of three different types have been recorded in Table 9. The soils under study showed a wide variation in soil texture may be due to differences in parent material, physiography *in situ* weathering and translocation of clay (Basava Raju *et al.*, 2005) and (Thangasamy *et al.*, 2005).

The data on mechanical composition of Lateritic soil reveals that, the percent sand content, 59.32, 37.00 and 32.52 percent at 0-30, 30-60 and 60-90 cms depths respectively. Similarly, the values of silt are 14.72, 28.0 and 36.0 percent and that for clay were 25.76, 35.0 and 31.48 percent at 0-30, 30-60 and 60-90 cms depths respectively. The sand content showed a declining trend with increase in depth of soil profile (0-30 to 60-90 cm). But silt content showed increasing trend with increase in soil depth (0-30 to 60-90 cm). Sharma *et al.*, (2004) reported that the sub-surface horizons of Lateritic soil exhibit higher clay content as compared to surface horizons due to the illuviation process occurring during soil development caused by high rainfall and high leaching rate. At all the two depths (30-60 and 60-90 cm) the soil profile exhibited a clay loam texture while the surface soil 0-30 cm of this profile observed the sandy clay loam texture. According to, Kadrekar *et al.*, (1981) these (Lateritic) soils were developed over granite/gneiss contains more sand and less clay as compared to soil derived from basalt.

In Medium black soil the mechanical composition was found to be, percent sand 39.88, 38.96 and 42.96, percent silt 24.36, 22.00 and 24.0 and percent clay 35.76, 39.06 and 33.04 at 0-30, 30-60 and 60-90 cms depths respectively. There was no definite trend seen with the percent increase or decrease according to depth. At all the three depths (0-30 and 30-60 and 60-90cm) of the Medium black soil profile exhibited a uniform clay loam texture. Finer texture characteristics of this soil in all depth of profile as compared to Lateritic soil might be because, these soils were developed over argillaceous basalt, and Deccan trap and hence produced higher amount of clay according to Patil and Prasad (2004).

The depth wise analysis of Coastal saline soil indicates that the percent sand, silt and clay at 0-30cm is 33.04, 40.96, 44.96 percent and 20.48, 28.0, 30.0 percent at 30-60cm and 46.48, 31.04, 25.04 percent at 60-90cm depths respectively. The sand and clay content followed an increasing trend with increase in soil profile depth. The silt content increased with

increase in soil depth 0-30 to 60-90cm of soil. At all the three depths (0-30 and 30-60 and 60-90 cm) the soil profile exhibited a (heavy) clay, clay loam, and loam texture respectively.

Both the soil viz., Coastal saline soil and Medium black soil are derived from Deccan trap however, the Coastal saline soil showed more fine and heavy texture at surface layer as compared to Medium black soil may be because of these (Coastal saline) soil near Arabian sea coast which remain submerged condition under continues tidal action which results into more weathering of soil and intrusion of finer texture particles in soil with tidal waves was studied by Joshi (1985). On the other hand according to Joshi and Kadrekar (1987) both (Medium black and Coastal saline) the soils derived from Deccan trap but only Coastal saline soil are impregnated with salts to varying degree according to their location in respect to sea results into heavy texture of soil.

In general, all three soil profiles of the Konkan region, showed a greater depth of 90 cm and therefore these are classified as deep soils. In Medium black and Coastal saline profile, the surface soil contains more clay as compared to Lateritic (Dapoli) surface soil. Similarly, the illuviation process also affected the vertical distribution of silt, clay and sand contents.

4.1.1.2 Bulk density of soil:

Bulk density is the mass of soil per unit volume including pore spaces (Hillel, 1980) and is considered as an important physical property of soils that influences the moisture availability, aeration and root penetration.

The bulk density of the Lateritic soil showed no much variation with depth, it ranged in between 1.25 to 1.28 Mg m⁻³. The others two soil types studied also did not vary much in their bulk density with depth and varied from 1.22 to 1.29 Mg m⁻³ for Medium black and 1.20 to 1.29 Mg m⁻³ for Coastal saline soils.

The variation in bulk density was attributed to variation in organic matter, texture *etc.* (Sharma and Anil Kumar, 2003). The results indicated that bulk density of soil profile of different location due to variation in clay content. Similar findings were also reported by Chavan *et al.*, (1995), Malvade (1993) and Mahajan (2001) for soils of Konkan. The variation in the bulk density of the soils may be due to elevated cultivation, organic matter and biotic activities in the surface soil than subsurface. While according to Thangasamy *et al.*, (2005), the increase in bulk density with depth was due to compaction of finer particles in deeper layers caused by over head weight of the surface soils.

In Coastal saline soil profiles bulk density showed decreasing trend with increasing depth. These results are in conformity with the findings of Shinde (2006), and Suryavanshi

(2010). The higher value for bulk density at surface layer 0-30 cm in coastal saline soil is due to heavy texture of soil whereas in the Lateritic type surface (0-30 cm) soil showed the lowest bulk density than others layer soil might be due to higher organic matter content in soil as reported by (Thangasamy *et al.*, 2005).

4.1.1.3 Porosity:

Data on overall Porosity of different soils when studied revealed that the Porosity of soil of all locations varied from 20.60 to 38.10 cm hr⁻¹. The observations recorded on porosity of soil in Table 9. The Porosity was minimum (20.60) in Panvel (Coastal saline) soil profile and maximum in Dapoli (Lateritic soil) soil profile (38.10 %). Porosity of soil is generally closely related to texture of soil. Among the two fine textured soil (Coastal saline and Medium black soil) the porosity was lowest in Coastal saline soil might be due to more heavy texture as well as more salts at the surface soil as compared to Medium black soil .

4.1.1.4 Infiltration rate:

Data on overall infiltration rate of different soils when studied revealed that the infiltration rate of soil of all locations varied from 0.9 to 2.1 cm hr⁻¹. The observations recorded on infiltration rate of soil in Table 9. The infiltration rate was minimum (0.90 cm hr⁻¹) in Panvel (Coastal saline) soil profile and maximum in Dapoli (Lateritic soil) soil profile (2.1cm hr⁻¹). Infiltration rate of soil is generally closely related to texture of soil. Among the two fine textured soils (Coastal saline and Medium black soil) the infiltration rate is lowest in Coastal saline soil might be due to more heavy texture as well as more salts at the surface soil as compared to Medium black soil (Joshi and Kadrekar, 1987). As the heavy texture as well as salts of Coastal saline soil pose the problem for infiltration of water. Higher infiltration rate value in Lateritic soil might be due to the coarse textured nature and low clay content of soil.

4.1.2 Chemical properties of soils:

The data on chemical properties of soil profiles determined is presented below. All three soil types under study were analysed at three different depths for various soil chemical properties like pH, electrical conductivity, available N, P, K, organic carbon, cation exchange capacity, DTPA extractable Fe, Mn, Zn, and Cu and various fractions of N, P and K (Table 10).

4.1.2.1. pH of soils:

The data on pH of soil profile sample of Lateritic soil, Medium black soil and Coastal saline soil have been presented in Table 10.

It is seen that the pH of soil at different depths (0-30, 30-60 and 60-90 cm) varied from 5.80 to 6.40, 6.9 to 7.2 and 7.3 to 8.4 for Lateritic, Medium black and Coastal saline soil, respectively. The data reveals that, in Lateritic soil the pH followed an increasing trend as the depth increased. The acidic pH of surface soil 0-30 cm might be due to acidic nature of parent material (granitic-gneiss) from which this soil derived. This slightly acidic to neutral nature of subsurface layer and increasing pH values at lower layer (30-60 cm and 60-90cm) of Lateritic profile may be attributed to the washing of bases due to heavy precipitation and simultaneous accumulation of iron and aluminium oxides resulting in the decrease of silica:sesquioxide ratio simultaneously makes the soil acidic in nature. Similar trend of finding of soil reaction of Lateritic soil profile have also been reported by (Mohaptra and Kibe 1973).

In Medium black soil, pH was found nearly neutral and it hardly showed any variation. The neutral nature of pH of this surface soil which attributed to content of high calcium/magnesium carbonates and other bases present in the soil. (Joshi and Kadekar 1987). The increase in this soil reaction (slightly alkaline) at subsurface layer 30-60cm could be due to leaching of bases from higher topography and getting accumulated at lower elevations and also high concentration of CaCO_3 in the lower areas. (Meena *et al.*, 2006).

In case of Coastal saline soil, pH was found neutral to alkaline in nature and showed increasing trend with increasing depth up to 60-90 cm. The neutral to alkaline of pH of this soil is due to these soil contains high exchangeable Na percent, preponderance of calcium, magnesium, chlorides and sulphates of sodium at surface soil and low permeability of soil for these bases makes the subsurface soil more alkaline than surface soil.

Table 10 : Chemical properties of different types of soil profiles studied.

Soil depth (cm)	pH	EC dS m ⁻¹	Organic carbon %	Organic matter %	CEC Cmole(P ⁺)kg ⁻¹	Av . Nitrogen kg ha ⁻¹	Av. P ₂ O ₅ kg ha ⁻¹	Av . K ₂ O kg ha ⁻¹	DTPA extractable micronutrient (mg kg ⁻¹)			
									Zn	Cu	Mn	Fe
Lateritic soil - Dapoli												
0-30	5.80	0.08	1.8	3.10	28.40	298.8	9.1	229.8	3.21	4.46	47.97	48.30
30-60	6.10	0.09	0.57	0.982	31.69	311.4	9.0	249.3	3.60	3.25	41.40	49.40
60-90	6.40	0.06	0.51	0.879	30.45	273.5	9.8	232.6	2.90	3.20	32.60	48.30
Medium Black soil - Karjat												
0-30	7.0	0.14	1.29	2.22	40.86	258.3	18.4	270	3.00	3.56	31.60	25.80
30-60	7.2	0.11	0.68	1.17	34.40	259.4	17.4	282.5	3.51	3.10	25.62	21.40
60-90	6.9	0.13	0.46	0.79	37.59	247.8	15.6	260.4	2.40	2.91	25.10	21.50
Coastal saline soil - Panvel												
0-30	7.3	3.8	0.78	1.34	46.6	312.4	23.4	972.8	3.25	5.87	22.60	23.80
30-60	8.4	4.2	0.50	0.862	49.4	302.3	20.5	972.0	3.10	4.20	28.90	28.40
60-90	8.4	3.0	0.20	0.34	41.4	308.4	16.5	982.6	3.10	3.80	29.10	29.20

Data on overall pH of different location when studied revealed that the pH of surface soil of all location varied from 5.8-7.3. Maximum soil samples of Konkan region showed near neutral pH range. Similar observations have also been reported by earlier workers (Kolpe 1987). The pH of surface soil at 0-30cm depth was found comparatively low in all the profiles as compared to subsurface soil layer of profiles might be due to the presence of high degree of base saturation in subsurface soil layers than surface layers. Similar observations have also been reported by earlier workers Salvi (1988).

4.1.2.2 Electrical conductivity of soils:

It can be observed from Table 10 that the data on electrical conductivity at different depth of soil profile ranged from 0.06 to 0.09, 0.11 to 0.14 and 3.0 to 4.2 dS m⁻¹ in Lateritic, Medium black and Coastal saline soil, respectively.

The electrical conductivity of soil was observed to be high in Coastal saline soil as compared with other two soil types. However, there was no regular trend observed as regards electrical conductivity and depths. On the other hand, the electrical conductivity of Lateritic soil and Medium black soil showed non saline nature of soil. Whereas the electrical conductivity of Coastal saline soil showed saline nature.

The electrical conductivity of Lateritic and Medium black soil was found to be low than Coastal saline soil might be attributed to removal of salts through leaching and surface runoff caused by heavy rainfall received in the Konkan region resulting into less concentration of soluble salts in soil.

Whereas the high electrical conductivity in Coastal saline soils were due to salinity developed due to ingress of sea water as well as poor drainage. According to Joshi (1985) ingress of sea water and intrusion of water from estuaries, creeks, drains and rivers increase salinity level in the cultivated lands all along, 8129 km of coastal tract. The increasing trend of electrical conductivity was found with increasing depth of soil might be due to the accumulation of larger amount of Na⁺, Mg⁺⁺ and Ca⁺⁺ in the surface as well as in the lower depths soils coastal zone near sea coast. Joshi and Kadrekar (1987) .

The overall data (Table 10) indicates that electrical conductivity of all the surface soils ranged from 0.08 to 3.8 dS m⁻¹, in which two soil (Lateritic and Medium black soil) are within the acceptable limit (non saline nature) and in Coastal saline soil have salinity hazards. According to Joshi (1985) due to relatively low rainfall coupled

with shallow saline water table and impeded drainage, the average value of EC of the soils in VRN zone (Coastal saline soil) was significantly higher than of the soils in VRL zone (Lateritic soil). Due to relatively low rainfall coupled with shallow saline water table and impeded drainage, the average value of EC of the soils in VRN zone was significantly higher than of the soils in VRL zone Joshi (1985).

4.1.2.3 Organic carbon and organic matter content of soils:

The organic carbon content of the soils under study is presented in Table 10. The data reveals that the percent organic carbon varied from 0.51 to 1.80 in Lateritic soil, 0.46 to 1.29 in Medium black soil and 0.20 to 0.78 in Coastal saline soils. Whereas the percent organic matter varied from 0.879 to 3.10 in Lateritic soil, 0.79 to 2.22 in Medium black soil and 0.34 to 1.34 in Coastal saline soils. The highest percent organic carbon and organic matter was found in Lateritic soil followed by Medium black and was lowest in Coastal saline soil.

There was a regular trend of decreasing in the percent organic carbon and organic matter as the depth increased in all the three soil profile under study. The surface soil (0-30cm) of all the soil profile were found to be higher organic carbon and organic matter than subsurface soil layers might be because of addition of organic material adding FYM or compost during cultivation.

According to Joshi and Kadrekar *et al.*, (1987) the organic carbon and organic matter content in the surface soil was relatively higher under both the zone which might be due to deposition of marine and vegetative residues into soil during the formation of these soil.

4.1.2.4 Cation exchange capacity of soils:

It would be seen from Table 10 that the cation exchange capacity of soils at different depth ranged from 28.40 to 31.69, 34.40 to 40.86, 41.4 to 49.4 c mole(P⁺)kg⁻¹ in Lateritic, Medium black and Coastal saline soil, respectively. The cation exchange capacity expressed in c mole (P⁺) kg⁻¹ of soils reveals that the cation exchange capacity was found to be maximum (46.6 c mole (P⁺) kg⁻¹) in Coastal saline soil followed by Medium black soil (40.86 c mole (P⁺) kg⁻¹) and was lowest (28.4 c mole (P⁺) kg⁻¹) in Lateritic soil. The minimum cation exchange capacity was exhibited by Lateritic soil. No regular pattern of the cation exchange capacity according to depth was observed.

The cation exchange capacity values of soil at different depth did not show any definite trend in all the profiles. It showed increasing trend in cation exchange capacity with increasing depth up to 0-30cm and 30-60 cm of profile in both soil (Lateritic and Coastal saline

soil) and thereafter at (60-90 cm depth) it showed a decline trend. In Medium black soil profile showed decreasing trend of cation exchange capacity with increasing depth of soil (0-30 to 30-60cm) and further increase in depth (60-90cm) showed a decline in cation exchange capacity. Similar results were quoted by (Gabhane *et al.*, 2006). Maximum cation exchange capacity was observed in the subsurface horizons as compared to surface soil in all the profile where elluviation of clay from surface to sub-surface horizon had taken place (Pillai and Natarajan, 2004).

In general the cation exchange capacity of three profile of this region ranged between 28.40 to 49.4 c mole (P⁺) kg⁻¹ in which higher value observed in Coastal saline soil (49.4-41.4 c mole (P⁺) kg⁻¹) followed by Medium black soil (34.40 - 40.86 c mole (P⁺) kg⁻¹) and found lowest in Lateritic soil (28.40-31.40 c mole (P⁺) kg⁻¹). The cation exchange capacity of surface soil of all profile varied from 28.40 to 49.4 c mol (P⁺) kg⁻¹ and the soils which had lower amount of clay content had lowest CEC values in the konkan region in Maharashtra. The results proved that, the cation exchange property is closely related to clay content in soil, as clay percent of soil increases it also increases. (Gupta *et al.* 1999). Lateritic soil exhibited low value of cation exchange capacity as compared to of coastal saline soil and medium black soil might be due to lower clay percentage. Low values of cation exchange capacity may be ascribed to the predominance of low CEC minerals, especially Illite and Kaolinite in lateritic soil (Sanjeev *et al.*, 2005). According to Patil and Prasad, (2004) cation exchange capacity of the soils with smectitic type of clay mineralogy (Coastal saline soil and medium black soil) was higher as compared to the soils with mixed mineralogy.

4.1.2.5 Available nitrogen in soils:

Nitrogen is the most vital major nutrient required by plants which is an essential component of all proteins and its deficiency results in stunted growth, slow growth and chlorosis in plants. As regards the nitrogen fertility status of soils the data presented in Table 10 indicates that the available nitrogen of three soils profiles samples ranged from 247.8 to 312.4 kg ha⁻¹

It would be seen from Table 10 that the available nitrogen at different depth of soil profile ranged from 273.5 to 311.0, 247.8 to 259.4, 302.3 to 312.4 kg ha⁻¹ in Lateritic, Medium black and Coastal saline soils, respectively. The available nitrogen values of soil at different depth did not show any definite trend in almost all profiles. It showed increasing trend in

available nitrogen with increasing depth upto 0-30 and 30-60 cm of profile and further at 60-90cm depth it showed a decline trend. In case of Coastal saline soil profile showed a decrease trend in available nitrogen with increasing depth of soil (0-30 to 30-60cm) however it increased in depth (60-90cm).

Overall in general the available nitrogen content of Lateritic and Medium black soil were low as compared to Coastal saline soil. The available nitrogen content in the konkan region of different surface soils was in order as Coastal saline soil > Lateritic > Medium black soils.

4.1.2.6 Available phosphorus in soils:

Phosphorus is important in plant bioenergetics and plays an important role in the conversion of light energy to chemical energy. As regards the initial phosphorous fertility status of three soils, the data presented in Table 10 indicates that the available phosphorus of three profile soils samples ranged from 9.0-23.40 kg ha⁻¹.

It would be seen from Table 10 that the available phosphorus at different depth of soil profile ranged from 9.0 to 9.8, 15.6 to 18.4, and 16.5 to 23.4 kg ha⁻¹ in Lateritic, Medium black and Coastal saline soils, respectively. The available phosphorus values of soil at different depths showed definite trend in Medium black and Coastal saline soils profiles except in Lateritic soil. It showed decreasing trend in available phosphorus with increasing depth of profile in Coastal saline and Medium black soil. It is evident that in general available P₂O₅ content in surface layer was found more in all the profile as compared to lower layers. There was no appreciable difference in its content at different depths, of the respective profiles except Coastal saline soil where it showed some variation. Thangaswamy *et al.*, (2005) stated that the higher content of phosphorous in Lateritic soil was due to confinement of crop cultivation to surface layer and supplementation of the depleted P₂O₅ through fertilizers. Sharma and Bali (2000) observed that the declining trend of phosphorous was due to higher fixation of it with depth.

The available phosphorus of Lateritic soil was low and it ranged from 9.0 to 9.8 kg ha⁻¹ as compared to the available phosphorus of Coastal saline soil and Medium black soil which ranged from 16.5 to 23.4 and 15.6 to 18.4 kg ha⁻¹, respectively. The available P₂O₅ content in the konkan region of different soils in surface (0-30cm) was in order as Coastal saline soil > Medium black soils > Lateritic. According to Prasunarani *et al.*, (1992) the low content of available P₂O₅ in Lateritic soils might be due to low native phosphorous content and fixation of released phosphorous by clay minerals and oxides of Fe and Al. Joshi and Kadrekar (1987)

reported that the saline soils are usually medium to high in phosphorus similarly they observed that saline soils, in general, were moderate in available phosphate due to use of the fertilizers in soils.

4.1.2.7 Available potassium in soils:

Potassium is absorbed by plants in higher amounts and helps in building of protein and photosynthesis. As regards the potassium fertility status of three soils of Konkan region, the data presented in Table 10 indicates that the available potassium of three soils samples ranged from 229.8 to 982.0 kg ha⁻¹

It would be seen from Table 10 that the available K₂O at different depth of soil profile ranged from 229.8 to 249.3, 260.4 to 282.0 and 972.0 to 982.0 kg ha⁻¹ in Lateritic, Medium black and Coastal saline soils, respectively.

The available K₂O values of soil at different depth did not showed any definite trend in almost all profiles. It showed decreasing trend in available potassium with increasing depth from 0-30 to 30-60 cm of profile in Coastal saline soil and thereafter it increase at 60-90 cm. In case of Lateritic and Medium black soils, the available K₂O trend found increased up to 30-60 cm depth, and thereafter a declined in both the soils at 60-90 cm depth.

The available potassium of coastal saline soil was found highest as compared to Lateritic soil and Medium black soil. According to Joshi and Kadrekar (1987) the higher available potassium value in Coastal saline soil associated with high salinity, indicating that potassium from the sea water might be one of the major source contributing to the higher soil potash.

4.1.2.8 DTPA extractable micronutrient:

The initial soil micronutrient fertility status at various depths of soils under study is mentioned in Table 10. The soils were analysed for DTPA extractable Zn, Cu, Mn and Fe expressed as mg kg⁻¹.

The DTPA extractable Zn content ranges from 2.90 to 3.60 mg kg⁻¹. The Lateritic soil showed the maximum variation in Zn content as far as the depth is of the profile is concerned. In Medium black soil, Zn content varied from 2.40 to 3.51 mg kg⁻¹ and the depth variation was observed in Coastal saline soil 3.25 to 3.10 mg kg⁻¹.

The DTPA extractable Cu content was in the range of 3.20 to 4.46 mg kg⁻¹ in Lateritic soil, 2.91 to 3.56 mg kg⁻¹ in Medium black soil and 3.80 to 5.87 mg kg⁻¹ in Coastal saline soils. There was definite trend of decreasing order of Cu content with the depth of soil sampling.

The Mn content was maximum in Lateritic soil and ranged from (32.60 to 47.97 mg kg⁻¹) followed by Medium black soil (25.10 to 31.60 mg kg⁻¹) and was minimum in Coastal saline soil (22.60 to 29.10 mg kg⁻¹). The Mn content showed definite trend of decreasing as the depth of sampling increased in Lateritic and Medium black soils however reverse trend of increase in Mn content as the depth increased in Coastal saline soils.

The DTPA extractable Fe content of Lateritic soil ranged in between 48.30 to 49.40 mg kg⁻¹, Medium black soil from 21.40 to 25.80 mg kg⁻¹ and that of Coastal saline soil from 23.80

Soil	Nitrogen fractions (mg kg ⁻¹)	Potassium fractions (mg kg ⁻¹)
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to 29.20 mg kg⁻¹. There was no much variation in Fe content of Lateritic soil as far as depth is concerned.

DTPA extractable Mn content in the soil was in the order of Lateritic soils followed by Medium black and Coastal saline soils. Similar trend in DTPA extractable Mn in these soils types was also reported by Vaidya (1988).

The higher DTPA extractable Fe in Lateritic soil than Medium black and Coastal saline soil might be due to acidic pH of Lateritic soil as reported by Yadav, (1988). He also observed that the decrease in DTPA extractable Fe contains as alkalinity increases in soil. The DTPA extractable Zn was found highest in Coastal saline soil followed by Lateritic and Medium black soil. Similar trend in DTPA extractable Zn in these soil types of konkan region was mentioned by Dabke (1987). The DTPA extractable Cu was found highest in Coastal saline soil followed by Lateritic soil and Medium black soil.

4.1.3 N, P and K fractions in soil profiles:

4.1.3.1 Nitrogen fractions in soil profiles:

4.1.3.1.1 Ammonical-N:

The data on ammonical-N content of soil profile of three different types have been recorded in Table 11. The data on ammonical nitrogen content of soil profile ranged from 20.1 to 29.5 mg kg⁻¹, 19.10 to 24.70 mg kg⁻¹ and 26.10 to 31.00 mg kg⁻¹ in Lateritic soil, Medium black soil and Coastal saline soil, respectively. (Table 11)

Table 11 : Nitrogen and potassium fractions in different types of soil profiles studied.

	Ammcl-N	Nitrate-N	Total N (Amm. + Nitrate)	Water sol-K	Exch. K	Ava. K	Non-Exch. K
Lateritic soil - Location Dapoli							
0-30	28.10	16.10	44.2	2.80	82.6	85.4	331.4
30-60	29.52	18.15	47.67	2.90	89.8	92.7	340.2
60-90	20.10	15.00	35.10	2.40	84.1	86.5	335.4
Medium Black soil - Location Karjat							
0-30	24.70	14.50	39.20	3.10	97.3	100.4	391.6
30-60	19.10	11.22	30.32	2.30	102.6	104.9	378.5
60-90	20.30	12.40	32.70	2.00	94.7	96.72	370.6
Coastal saline soil - Location Panvel							
0-30	31.00	19.40	50.40	128.6	233.2	361.8	432.4
30-60	26.10	17.28	43.38	120.0	241.6	361.6	428.8
60-90	28.80	18.65	47.45	120.0	254.5	365.5	402.6

The mineralizable nitrogen in soil plays a dominant role in nutrition to crops. Both organic and inorganic sources are applied to soil to meet the nitrogen requirement of crop. But the nitrogen fertility status of soils is generally governed by the ammonical and nitrate nitrogen content in soils because these two forms of nitrogen are required in large quantity for plant nutrition. Plant takes nitrogen only in these forms for their growth. Soils differ widely in their capacity to retain ammonical and Nitrate nitrogen due to variation in physico-chemical properties of soil. To assess the nitrogen fertility status of soils these forms of nitrogen were analyzed. The N content in three soil profiles of different soil types is presented in Table 11.

The ammonical-N values of soil at different depth did not show any definite trend in almost all profiles. It showed an increasing trend in ammonical-N with increasing depth up to 0-30 and 30-60 cm of profile in the Lateritic soil. Thereafter at 60-90cm depth it showed a declined trend.

In case of Coastal saline soil profile showed decreasing trend in ammonical-N with increasing depth of soil (0-30cm to 30-60cm) and again with increase in depth (60-90cm) showed slight increase in ammonical-N.

4.1.3.1.2 Nitrate-N:

It is seen from the nitrate-N content of soil profile ranged from 15.00 to 18.15 mg kg⁻¹, 11.22 to 14.50 mg kg⁻¹ and 17.28 to 19.40 mg kg⁻¹ in Lateritic soil, Medium black and Coastal saline soil, respectively.

The nitrate-N values of soil at different depth did not show any definite trend in almost all profiles. It showed increasing trend with increasing depth upto 0-30 and 30-60 cm of profile in the Lateritic soil and further at 60-90cm depth it showed a declined trend. Similar observation was reported by Dongale (1989). In case of Coastal saline and Medium black soil profile showed decreasing trend in nitrate-N with increasing depth of soil (0-30 cm to 30-60cm) and further increase at depth (60-90cm). Similar results were quoted by Patil (1986) for the Lateritic and Medium black soils of konkan region.

4.1.3.1.3 Total (ammonical + nitrate)-N:

As seen from the Table 11 total ammonical+nitrate-N content of three soils at different depth varied from 30.32 to 50.40 mg kg⁻¹. Total ammonical+nitrate-N content of soil profile ranged from 35.10 to 47.67 mg kg⁻¹, 30.32 to 39.20 mg kg⁻¹, 43.38 to 50.40 mg kg⁻¹ in Lateritic soil, Medium black soil and Coastal saline soil, respectively.

The total ammonical + nitrate-N values of soil at different depth did not show any definite trend in almost all profiles. It showed an increasing trend with increasing depth upto 0-30 and 30-60 cm in the Lateritic soil and further at 60-90cm depth it showed a decline trend. In case of Coastal saline and Medium black soil profile showed decreasing trend in total (ammonical + nitrate) - N content with increasing depth of soil (0-30 cm to 30-60cm) and further with increased at depth (60-90cm).

The data as regard the fertility status, on all forms of nitrogen in surface soil was observed that N-form status followed the trend Coastal saline soil < Lateritic soil < Medium black soil. Total (ammonical + nitrate)-N content was lower in Medium black and Lateritic soil profile than Coastal saline soil.

4.1.3.2 Potassium fractions in soil

The various potassium fractions viz. water soluble-K, exchangeable-K, available (water soluble+exchangeable)-K, , and nonexchangeable-K in different soil profiles viz Lateritic soil, Medium black and Coastal saline soils of Konkan region at different depth are estimated. The data obtained on their content in relation to various depth of soil have been recorded in Table 11.

4.1.3.2.1 Water soluble-K

The data on water soluble K in soil at different depths in three soils viz. Lateritic soil, Medium black and Coastal saline soil of Konkan region, have been presented in Table 11.

It could be seen from the data that, these form of K were varying markedly in between the different soil types. However within a soil types water soluble K content at different depth varied from minimum to a maximum viz., 2.40 to 2.90 mg kg⁻¹, 2.0 to 3.10 mg kg⁻¹ and 120.0 to 128.0 mg kg⁻¹ in Lateritic soil, Medium black and Coastal saline soils respectively.

The water soluble-K content followed increasing trend with increase in soil depth at 0-30 and 30-60cm but decreased at 60-90 cm depth in Lateritic soil profile. Whereas in both (Coastal saline and Medium black soil) soil profile followed decreasing trend with increase in soil depth at 0-30 to 60-90 cm in depth. These findings indicated that the surface soil layer 0-30cm of the profile contained higher amount of water soluble k except Lateritic soil profile. It might be due to intense weathering in surface soil layer and release of K from organic residues in soil. Similar trend was observed as regards to water soluble-K content in soil profile has been reported by Kadrekar (1977) in black soils of Maharashtra. However, in the Lateritic soil profile, subsurface layer (30-60cm) contain higher amount of water soluble-K content might be due to its presence in solution form so it could be leached easily or it may be washed due to high rainfall and leaching losses through water from upper layer to subsurface layer.

The water soluble-K of Lateritic and Medium black soil were in general low and it ranged from 2.40 to 2.90 mg kg⁻¹ and 2.00 to 3.10 mg kg⁻¹, respectively as compared to Coastal saline soil (120.0 to 128.0 mg kg⁻¹) at all the depth of soil profile. The higher content of water soluble K in Coastal saline soil profile is attributed to its being saline and potassium content as major accumulated salts added through sea water tides (Joshi 1985). Similar observations were also recorded by earlier worker (Mali 1989). Lateritic surface soil (0-30cm) content was found low water soluble-K as compared to Medium black soil because of low capacity to retain cation as a result of low clay percentage. Similar observations for water soluble-K content in soil have been reported by Kadrekar (1977).

As the water soluble K in non saline lateritic and medium black soil profile did not exceed the maximum value of 3.1 mg kg⁻¹. It indicated that, it is important to maintain the water soluble K in soil because this is one form of potassium which is taken up by plant for their nutrition and growth.

4.1.3.2.2 Exchangeable-K

The exchangeable-K is the form of K in soil which is retained loosely by finer particles present in soil. Thus, the exchangeable-K content varies in soils depending upon types of soil texture.

The data on exchangeable-K in soil at different depths in three soil viz. Lateritic, Medium black and Coastal saline soils of Konkan region, have been presented in Table 11. It is evident from the data that, it varies from 82.60 to 89.80 mg kg⁻¹, 96.70 to 102.6 mg kg⁻¹ and 233.2 to 254.5 mg kg⁻¹ in Lateritic, Medium black and Coastal saline soil, respectively.

The exchangeable-K content followed an increasing trend with increase in soil depth at 0-30 cm and 30-60 cm but decreased at 60-90 cm depth in Lateritic and Medium black soil profiles. Whereas the exchangeable-K content followed increasing trend with increase in soil depth at 0-30 to 60-90 cm in depth in Coastal saline soil profile.

Similar trend as regards to exchangeable-K content in soil profile has been reported by Kadrekar (1977) in black soils of Maharashtra and Mali (1989) in Lateritic and Coastal saline soil. In the Lateritic and Medium black soil profile, lower exchangeable-K content at surface layer (0-30cm) as compared to their respective subsurface layer (30-60cm) may be attributed to depletion of exchangeable -K because of crop cultivation with addition of low amount of potassium fertilizers than required, or high leaching resulting in the movement of exchangeable-K in the subsoil layer. Similar findings were also noticed by Kadrekar (1977) in deep black soil of Maharashtra, and Chandel (1976) in Lateritic soil of Konkan.

In general the exchangeable-K of Lateritic and Medium black soil were low and it ranged from 82.6 to 89.8 mg kg⁻¹ and 97.32 to 102.6 mg kg⁻¹, respectively as compared to Coastal saline soil (233.2 to 254.5 mg kg⁻¹) at all the depths of soil profile. This was found to be two to three times higher in Coastal saline soil than other two soils which might be because of the soils being saline and contain potassium as major salts added through sea water source continuously and makes soil profile containing potassium rich. (Joshi 1985). Similar observations were also recorded by earlier workers (Mali 1989). Lateritic surface soil (0-30cm) content was found to be low exchangeable-K as compared to Medium black soil because of low capacity to retain cation as a result of low clay percentage. Similar observations as regards to water soluble-K content in soil have been reported by Kadrekar (1977).

The above results showed that capacity of soil to retain loosely bound exchangeable-K is depending upon finer particles viz, clay percent. As clay percent increases the exchangeable-K content also increases in different soil types.

4.1.3.2.3 Available-K

The data presented in Table 11 available-K (water soluble-K + exchangeable K) in soil at different depths in three soil types Lateritic, Medium black and Coastal saline soil of Konkan region.

The data reveals that, available-K content at different depth of soil profile ranged from 85.6 to 92.7 mg kg⁻¹, 96.72 to 104.9 mg kg⁻¹, 361.6 to 365.5 mg kg⁻¹ in Lateritic soil, Medium black and Coastal saline soil, respectively.

The available-K values of soil at different content at depth did not show any definite trend in the profiles. In case of Lateritic and Medium black soils, the available potassium trend found to increase up to 30-60 cm depth, and thereafter it declined at 60-90 cm depth.

The available potassium of Coastal saline soil was found to be highest as compared to Lateritic and Medium black soil. According to Joshi and Kadrekar (1987) the higher available potassium value in coastal saline soil associated with high salinity, indicating that potassium from the sea water might be one of the major source contributing to the higher soil potassium.

4.1.3.2.4 Nonexchangeable-K

The non exchangeable-K is the form of K in soil which tightly retained by finer particles present in soil. Thus, the non exchangeable-K is called as fixed-K. The non exchangeable-K content value is found different in soils depending upon types of soil texture.

The data on non exchangeable-K in soil at different depths in three soil viz. Lateritic, Medium black and Coastal saline soils of Konkan region, have been presented in Table 11. It could be seen from the data that, it varied from 331.4 to 340.2 mg kg⁻¹, 370.6 to 391.6 mg kg⁻¹ and 402.6 to 432.4 mg kg⁻¹ in Lateritic soil, Medium black and Coastal saline soil, respectively.

The non exchangeable-K content followed increasing trend with increase in soil depth at 0-30cm and 30-60 cm but decreased at 60-90cm depth in Lateritic soil profile. Whereas the non exchangeable-K content followed decreasing trend with increase in soil depth in both (Coastal saline and Medium black soil) profile.

Similar trend as regards to non exchangeable-K content in soil profile has been reported by Kadrekar (1977) in black soils of Maharashtra and Mali (1989) in Lateritic and Coastal saline soil. However in the Medium black soil the higher content of non exchangeable-K was found at surface layer (0-30cm) as compared to their respective subsurface layer (30-60 cm) may be due to higher release rate of potassium from total-K which is attributed due soil derived from K rich mineral. There were no marked differences in the non exchangeable K content in depths of soil profile. Similar findings were also noticed by Kadrekar (1977) in Maharashtra deep black soil and Chandel (1976) in Lateritic soil of Konkan.

The non exchangeable-K of Lateritic and Medium black soil were general low and it ranged from 331.4 to 340.2 mg kg⁻¹ and 370.6 to 391.6 mg kg⁻¹, respectively as compared to Coastal saline soil (402.6 to 432.4 mg kg⁻¹) at all the depth of soil profile. The nonexchangeable-K in Coastal saline soil profile was found to be higher than other two soils as it might be because of the soils being saline and contain potassium as major salts added through sea water source continuously and makes all the depth of soil profile containing potassium rich. (Joshi 1985). Similar observations were also recorded by earlier worker (Mali 1989). Lateritic surface soil (0-30cm) were found low in exchangeable-K as compared to Medium black soil, this might be due to low capacity to retain cation as a result of low clay percentage or depletion due to crop cultivation. Similar observations of water soluble-K content in soil have been reported by Kadrekar (1977).

The above results showed that capacity of soil to retaining non exchangeable-K is depending upon finer particles *viz*, type and amount of clay percent present in soil. As clay percent increases the nonexchangeable-K content also increases in different soil types.

Since the results on non exchangeable-K content for three soils profile did not exceed more than 1000 mg kg⁻¹, all the soil profile came under the low category of non exchangeable-K status.

4.1.3.3: P fractions in soils:

In soil P exists both in organic as well as inorganic form. But inorganic P is the predominant form of soil P, constituting 60-80 percent of total P (Tomar 2003). Amongst the various inorganic form of P, Ca-P, Al-P and Fe-P are known as active forms, however the saloid-P, occluded-P and reductant soluble-P are known as less active P form exists in soil. Knowledge on forms of phosphorous, their relationship with other soil property is very useful in assessing phosphorous nutrition to crops. Therefore emphasis was given to determine the content of these fractions in the soils under present study.

The various soils inorganic P forms viz., Ca-P, Al-P, Fe-P, saloid-P, occluded-P, reductant soluble-P and total inorganic-P content in soil profiles of Lateritic, Medium Black and Coastal saline soil of Konkan region at three different depths are analyzed. The data obtained on their content in relation to depth of soil have been recorded in Table 12.

4.1.3.3.1 Saloid - P:

The data on saloid-P content of three soil profile at three different depths have been recorded in Table 12.

Table 12: Phosphorous fractions in different types of soil profiles studied..

Soil depth (cm)	Phosphorous fractions (mg kg ⁻¹)						
	Saloid-P	Al-P	Fe-P	Ca-P	Occluded-P	Reductant soluble-P	Total inorganic P
Lateritic soil - Location Dapoli							
0-30	2.3	62.4	128.0	29.1	56.4	103.0	381.1
30-60	2.1	52.8	132.4	19.3	62.3	110.4	379.3
60-90	0.9	52.3	132.4	12.1	59.3	119.5	376.5
Medium Black soil - Location Karjat							
0-30	4.2	43.4	49.3	102.1	32.4	82.4	313.8
30-60	4.3	40.4	43.8	105.4	35.0	88.4	317.3
60-90	4.3	37.4	44.3	90.6	28.2	82.3	287.1
Coastal saline soil - Location Panvel							
0-30	8.9	52.6	59.6	113.8	35.2	84.4	354.5
30-60	9.4	56.2	52.3	108.5	32.3	89.2	347.9
60-90	6.2	53.4	52.0	108.5	38.4	90.5	349.0

It is evident from the data that the saloid-P content varied from 2.3 to 8.9 mg kg⁻¹, 2.1 to 9.4 mg kg⁻¹ and 0.9 to 6.2 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively.

The saloid-P content of soil profile ranged from 0.9 to 2.3, 4.2 to 4.3 mg kg⁻¹ and 6.2 to 8.9 mg kg⁻¹ in Lateritic, Medium black and Coastal saline soils respectively. The saloid-P content in Lateritic soil showed a declining trend with increase in depth. Tamboli and Daftardar (2003) reported the similar observations in Lateritic soils of konkan region. Ram and

Mukhopadhyay (2008) and Dasog *et al.*, (2010) also quoted that the saloid-P content in for Alfisol soils of west Bengal ranged between 0.62 - 3.50 mg kg⁻¹.

The saloid-P content of Medium black soil revealed that there was no much variation observed as regards saloid-P content and depths. The saloid-P content of Medium black soil showed an increasing trend with increase in depth up to 0-30 and 30-60cm and thereafter variation not observed in saloid-P content in between 30-60 and 60-90cm depth.

The saloid - P content of Coastal saline soil revealed that, there was no regular trend observed as regards saloid-P content and depths. In case of Coastal saline soil profile showed increasing trend in saloid-P content with increasing depth of soil (0-30 to 30-60cm) and further increase in depth (60-90cm) showed a decline trend.

The data as regards to the form of P in soil profile of surface soil was observed that saloid-P content followed the trend viz., Coastal saline soil >Medium black soil>Lateritic soil. Tamboli and Daftardar (2003) reported that, the saloid-P content in Medium black soils of Rahuri is higher as compared to Lateritic soils of Konkan region. The saloid-P content of soil was observed to be high in Coastal saline soil as compared with other two soil (Lateritic and Medium black soil) types.

The saloid-P content did not show wide variation with depth in all the three soil profiles, which may be because of its very low concentration in soils. It has been observed that the saloid bound-P is the least among the all P fractions which also been reported by many authors Dongale, (1989) and Ram and Mikhopadhyay (2008) in different soil types of states.

4.1.3.3.2 Al-P:

The data on Al-P content of soil profile of three different types have been recorded in Table 12. The Al-P content of Lateritic soil reveals that, the mg kg⁻¹ Al-P content, 62.4, 52.8 and 52.3 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively.

The Al-P content showed a declining trend with increase in depth profile of Lateritic soil. Dasog *et al.*, (2010) reported that the Al-P content in Lateritic soils of West Bengal varied between 23.52 to 50.00 mg kg⁻¹.

The Al-P content of Medium black soil reveals that, the mg kg⁻¹ Al-P content content, 43.4, 40.3 and 37.3 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The Al-P content showed a decreasing trend with increase in depth of soil profile. Niranjana *et al.*, (2012) reported that the Al-P content in Vertisol soils of Karnataka varied between 46.59 to 60.50 mg kg⁻¹.

The Al-P content of Coastal saline soil reveals that, the Al-P content, 52.6, 56.2 and 53.4 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. However, there was no regular trend observed as regards Al-P content and depths. In case of Coastal saline soil profile showed increasing trend in Al-P content with increasing depth of soil (0-30 to 30-60cm) and further increase in depth (60-90cm) showed a decline in Al-P content.

The Al-P content of soil profile of three different types was ranged from 40.4 to 62.4 mg kg⁻¹. The Al-P content of soil was observed to be higher in Lateritic soil as compared with others two soil types. Under acid (Lateritic) condition of soil increased solubility of aluminium induces the high Al-P status of soil due to acidic nature. Tamboli and Daftardar (2003) reported that the Al-P content in Medium black soils of Rahuri is lower as compared to Lateritic soils of konkan region. According to Dasog *et al.*, (2010) the Al-P is the dominant fraction in Lateritic soil due to its acidic nature and its content decreases with increasing pH.

4.1.3.3.3 Fe-P:

The data on Fe-P content of soil profile of three different types have been recorded in Table 12. The Fe-P content of Lateritic soil reveals that, the Fe-P content, 128.0, 132.4 and 132.4 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The Fe-P content showed an increasing trend with increase in depth of soil profile. Dasog *et al.*, (2010) reported that the Fe-P content in Lateritic soils of West Bengal varied between 95.2 to 120.0 mg kg⁻¹. Ram and Mukhopadhyay (2008) reported that Fe-P of West Bengal Lateritic soil ranged from 23.3 to 150.0 mg kg⁻¹.

The Fe-P content of Medium black soil reveals that, the Fe-P content, 49.3, 43.8 and 44.3 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The Fe-P content showed a decreasing trend with increase in depth of soil profile up to 30-60 thereafter with increase in depth at 60-90 cm Fe-P status showed increasing trend. Singh *et al.*, (2003) reported that, the Fe-P content in Medium black soils varied between 21.6 to 40.6 mg kg⁻¹.

The Fe-P content of Coastal saline soil revealed that, the Fe-P content, 59.6, 52.3 and 52.0 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. In case of Coastal saline soil profile showed decreasing trend in Fe-P content with increasing depth of soil. Khadtar *et al.*, (1991) reported that the Fe-P content in Konkan Coastal zone of Maharashtra varied between 74.0 to 209.0 mg kg⁻¹. Joshi and Kadrekar (1987) found the similar results for Fe-P in Coastal saline soils of Konkan region.

The Fe-P content of soil profile of three different types was ranged from 43.8 to 132.4 mg kg⁻¹. The Fe-P trend of three soil types under study was found as viz., Lateritic soil > Coastal saline soil > Medium black soil. The Fe-P content of soil was observed to be higher in Lateritic

soil as compared with others two soil types. According to Dasog *et al.*, (2010) the Fe-P is the dominant fraction in acid Lateritic soil. Under acid condition of soil (Lateritic) increased solubility of Fe induces the high Fe-P status of soil. Tamboli and Daftardar (2003) reported that the Fe-P content in Medium black soils of Rahuri is lower as compared to Lateritic soils of konkan region. But Coastal saline soil found to be higher in Fe-P status than Medium black soil.

4.1.3.3.4 Ca-P:

The data on Ca-P content of soil profile of three different types have been recorded in Table 12. The Ca-P content of Lateritic soil revealed that, the Ca-P content, 29.1, 19.3 and 12.1 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The Ca-P content showed a decreasing trend with increase in depth of soil profile. Dasog *et al.*, (2010) reported that the Ca-P content in lateritic soils of West Bengal varied between 14.1 to 20.0 mg kg⁻¹. Ram and Mukhopadhyay (2008) reported that the Ca-P content in Lateritic soils of West Bengal varied between 5.33 to 42.0 mg kg⁻¹.

The Ca-P content of Medium black soil revealed that, the Ca-P content, 102.1, 105.4 and 90.6 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The Ca-P content showed an increasing trend with increase in depth of soil profile upto 30-60 and 60-90 cm thereafter with increase in depth at 60-90cm Ca-P status showed declined trend. Niranjana *et al.*, (2012) reported that the Ca-P content in non saline vertisol of Karnataka varied between 70.57 to 350.84 mg kg⁻¹. They also reported that among the all P-fraction, Ca-P is the dominant fraction in Vertisol soil.

The Ca-P content of Coastal saline soil reveals that, the Ca- P content, 113.8, 108.5 and 108.5 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. In case of Coastal saline soil profile showed decreasing trend in Ca-P content with increasing depth of soil. Joshi and Kadrekar (1987) found the similar results in Coastal saline soil of Konkan region.

The Ca-P content of soil profile of three different types was ranged from 12.1 to 113.8 mg kg⁻¹. The Ca-P trend of three soil types under study was found as viz., Coastal saline soil > Medium black soil > Lateritic soil.

The Ca-P content of soil was observed to be higher in Coastal saline soil as compared with others two soil types. Joshi and Kadrekar (1987) also reported that among the all P-fraction, Ca-P is the dominant fraction in Coastal saline soil of konkan region. They also reported that under saline condition of soil increased accumulation of Ca from sea water intrusion induces the high Ca-P status of Coastal saline soil.

The Ca-P content of soil was observed to be higher in Medium black soil as compared with Lateritic soils types. According to Tamboli and Daftardar (2003) the Ca-P is the dominant fraction in slightly acidic to alkaline (Black) soil. As both the Coastal saline and Medium black soils are belongs to Vertisol and developed on basaltic parent material but Ca-P content was observed to be higher in Coastal saline soil as compared with medium black soil may be because of low status of Ca in Medium black soil results due to the development of this soil from the non calcareous to low calcareous basaltic parent material without intrusion of sea water as a calcium source. Whereas Tamboli and Daftardar (2003) reported that the Ca-P content in Medium black soils of Rahuri is higher as compared to Lateritic soils of konkan region due to higher Ca status in Medium black soil.

This trend might have contributed to higher Ca status in soil because according to Bear (1965) CaCO_3 solubility increases with increasing pH and increasing Ca-P status in soil.

4.1.3.3.5 Occluded - P:

The data on occluded-P content of soil profile of three different types have been recorded in Table 12. The occluded-P content of Lateritic soil reveals that, the occluded-P content, 56.4, 62.3 and 59.3 mg kg^{-1} at 0-30, 30-60 and 60-90 cms depths respectively. The occluded-P content showed an increasing trend with increase in depth of soil profile up to 30-60 cm thereafter with increase in depth at 60-90cm occluded-P status showed declined trend. Mujumdar *et al.*, (2007) reported that the occluded-P content in Alfisol soils of Meghalaya varied between 78.0 to 80.0 mg kg^{-1} .

The occluded-P content of Medium black soil revealed that, the occluded-P content, 32.4, 35.0 and 28.2 mg kg^{-1} at 0-30, 30-60 and 60-90 cms depths respectively. The distribution of occluded-P did not follow any definite pattern with depth. The occluded-P content showed a increasing trend with increase in depth of soil profile up to 30-60 and 60-90 cm thereafter with increase in depth at 60-90cm occluded-P status showed declined trend Niranjana *et al.*, (2012) reported that the occluded-P content in non saline Vertisol of Karnataka varied between 21.32 - 135.29 mg kg^{-1} .

The occluded-P content of Coastal saline soil revealed that, the occluded-P content, 35.2, 32.3 and 38.4 mg kg^{-1} at 0-30, 30-60 and 60-90 cms depths respectively. In case of Coastal saline soil profile showed decreasing trend in occluded-P content with decreasing depth of soil profile up to 0-30 and 30-60 cm thereafter with increase in depth at 60-90 cm occluded-P status showed increasing trend. Khadtar *et al.*, (1991) reported that the occluded-P content in Konkan Coastal zone of Maharashtra varied between 25.0 to 77.0 mg kg^{-1} .

The occluded-P content of soil profile of three different types was ranged from 28.2-62.3 mg kg⁻¹. The occluded-P content of soil was observed to be higher in Lateritic soil as compared with others two soil types. According to Khan and Mandal (1973), occluded-P form of P could be twice as dominant in Lateritic soil than in neutral - alkaline Medium black soils.

4.1.3.3.6 Reductant soluble-P:

The data on reductant soluble-P content of soil profile of three different types have been recorded in Table 12. The reductant soluble-P content of Lateritic soil reveals that, the reductant soluble-P content, 103.0, 110.4 and 119.5 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The reductant soluble-P content showed an increasing trend with increase in depth of soil profile. Ram and Mukhopadhyay (2008) reported that the reductant soluble-P content in Alfisol soils of Meghalaya varied between 45.3 to 146.6 mg kg⁻¹.

The reductant soluble-P content of Medium black soil reveals that, the reductant soluble-P content, 82.4, 88.4 and 82.3 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The distribution of reductant soluble-P did not follow any definite pattern with depth. The reductant soluble-P content showed a increasing trend with increase in depth of soil profile up to 30-60 cm thereafter with increase in depth at 60-90cm it showed declined trend

The reductant soluble-P content of Coastal saline soil reveals that, the mg kg⁻¹ reductant soluble-P content, 84.4 89.2, and 90.5 at 0-30, 30-60 and 60-90 cms depths respectively. In case of Coastal saline soil profile showed increasing trend in reductant soluble-P content with increasing depth.

The reductant soluble-P content of soil profile of three different types was ranged from 82.3 to 119.5 mg kg⁻¹. The reductant soluble-P content of soil was observed to be higher in Lateritic soil as compared with others two soil types. Tamboli and Daftardar (2003) also reported that reductant soluble-P of Rahuri is low (47.7 mg kg⁻¹) as compared to reductant soluble-P (63.45 mg kg⁻¹), of Lateritic soils of konkan region. The higher values of reductant soluble-P in Lateritic soil was also reported by Dongale (1993) which was attributed to higher content of sesquioxides.

4.1.3.3.7 Total inorganic-P:

The data on total inorganic-P content of soil profile of three different types have been recorded in Table 12. Total inorganic-P content in soil was estimated by addition of all the inorganic forms of P.

The total inorganic-P content of Lateritic soil reveals that, the total inorganic-P content, 381.1, 379.3 and 376.5 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The total inorganic-P content showed a decreasing trend with increase in depth of soil profile. Lungmuana *et al.*, (2012) reported that total inorganic-P of Lateritic soils of west Bengal ranged between 94 - 379 mg kg⁻¹

The total inorganic-P content of Medium black soil reveals that, the total inorganic-P content, 313.8, 317.3 and 287.1 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. The distribution of total inorganic-P content showed a increasing trend with increase in depth of soil profile upto 30-60cm.

The total inorganic-P content of Coastal saline soil revealed that, the total inorganic-P content, 354.5, 347.9, and 349 mg kg⁻¹ at 0-30, 30-60 and 60-90 cms depths respectively. In case of Coastal saline soil profile showed decreasing trend in total inorganic-P content with increasing depth of soil profile upto 30-60 cm.

The total inorganic-P content of soil profile of three different types was ranged from 313.8 to 379.3 mg kg⁻¹. The total inorganic-P content of soil was observed to be higher in Lateritic soil as compared with others two soil types. Tamboli and Daftardar (2003) reported that total inorganic-P of Vertisol of Rahuri is low as compared to total inorganic-P of Lateritic soils of Konkan region. Dongale (1989) observed the similar results for the total inorganic-P fractions of Medium black and Lateritic soils of Konkan region.

A. Experiment-I

4.2 Leaching losses of primary nutrients and pesticides at different growth stages of lowlandrice crop as affected by various treatments. (Experiment -I)

The data regarding the leaching losses of the NPK and pesticides from soil under rice crop at different growth stages (30, 60 and 90DAT) as influenced by various treatments for both the years of experiment are discussed below.

4.2.1 Leaching losses of Nitrogen:

The data regarding the leaching losses of the nitrogen from soil at different growth stages (30, 60 and 90DAT) of rice crop as influenced by various treatments is given in Table 13 and 14 for first and second year of experiment. The leaching losses of the nitrogen in the leachates were analyzed for both the form of nitrogen ammonical-N, and nitrate-N from soil.

4.2.1.1 Ammonical- N (NH₄⁺-N):

The data presented in Table 13 and 14 (Fig 1, 2, 3 , 5, 6 and 7) reveals that the leaching losses of ammonical-N from soil under rice crop were observed to vary from 5.39 to 39.22 mg pot⁻¹ and 7.05 to 38.39 mg pot⁻¹ among the different treatments in first and second year of experiment, respectively. The data indicates that the leaching losses of ammonical-N under various treatments were significantly influenced.

Leaching losses of ammonical-N from rice growing pots having Lateritic soil under rice, varied from 38.48 to 39.22 mg pot⁻¹, 30.96 to 31.73 mg pot⁻¹ and 27.79 to 29.31 mg pot⁻¹ on 30, 60 and 90 DAT respectively during first year of experiment while in second year of experiment, its content varied from 36.24 to 38.39 mg pot⁻¹, 26.96 to 28.62 mg pot⁻¹ and 25.65 to 25.94 mg pot⁻¹ on 30, 60 and 90 DAT respectively. In the Medium black soil, leaching losses of ammonical-N varied from 24.19 to 25.16 mg pot⁻¹, 20.77 to 21.36 mg pot⁻¹ and 18.21 to 18.43 mg pot⁻¹ on 30, 60 and 90 DAT respectively during first year of experiment while in second year of experiment, its content varied from 31.57 to 31.94 mg pot⁻¹, 24.12 to 24.70 mg pot⁻¹ and 18.48 to 18.96 mg pot⁻¹ on 30, 60 and 90 DAT respectively. In Coastal saline soil, the leaching losses of ammonical-N content varied from 9.49 to 9.84 mg pot⁻¹, 9.00 to 9.16 mg pot⁻¹ and 5.39 to 5.67 mg pot⁻¹ on 30, 60 and 90 DAT respectively during first year of experiment while in second year of experiment, its content varied from 11.84 to 12.37 mg pot⁻¹, 7.93 to 8.27 mg pot⁻¹ and 7.05 to 7.33 mg pot⁻¹ on 30, 60 and 90 DAT respectively. The leaching losses of ammonical-N was found to be significantly superior in T₃ (Lateritic soil + RDF + Phorate) treatment at each sampling period in the both the years of experiment. However, the treatments T₁ and T₂ were observed to be at par with T₃ treatment and significantly superior over remaining all the other treatments.

The data recorded in Table 13 and 14 on leaching losses of ammonical-N revealed that the leaching loss of ammonical-N at 30 DAT was maximum as compared to 60 DAT and 90 DAT of sampling. The maximum leaching loss of ammonical-N occurred at 30 DAT and afterwards it showed a gradually declining trend in subsequent observations and it was recorded minimum on 90 DAT in both the years of experiment. The declining trend in leaching loss of ammonical-N it may be because of utilization of ammonical-N by crop. The ammonical-N content in the leachate was highest at 30 DAT due to highest disintegration of aggregates, unclogged soil pores, limited utilization of applied N by the establishing rice seedlings, then markedly declined

from 60 and 90 DAT due to higher root development and foraging capacity of plant. (Suresh *et al.*, 1994).

The total (0-90 DAT) leaching loss of ammonical-N was observed maximum (13.37 to 15.08 percent of applied quantity) from the Lateritic soil followed by Medium black soil (9.5 to 11.37 percent) and was minimum in Coastal saline soil (3.59 to 4.21 percent).

The data on ammonical-N leaching loss in various soil types found that maximum leaching loss of ammonical-N was seen in Lateritic soil followed by Medium black and Coastal saline soil. Lateritic soil is being light textured and low CEC and higher infiltration rate while favoured easy downward movement of leachate as compared to other two soil types (Medium black and Coastal saline soil). High cation exchange capacity in Vertisol possibly caused greater retention as well as lower hydrolysis of urea (Purakayastha and Katyal 1998). Within the different soils under study the total quantity of ammonical-N leaching losses was found to be more in Lateritic (Dapoli) soil. Velu and Ramanathan (1998) reported that leaching loss of ammonical-N are more in soils dominated by Kaolinite type 1:1 type mineral. The leaching losses of ammonical-N were recorded less in soils dominated by 2:1 type smectite clay minerals. This clay has a higher retention capacity as compared to Kaolinite type 1:1 type minerals.

The lowest value of leaching loss of ammonical-N in percolates of Coastal saline soil can be attributed to its saline nature. Bandhopadyay and Bandhopadyay (1983) observed that the rate of mineralization of nitrogen was slowed down by increase in soil salinity. The rate of conversion of one form of N to other form is quite slow in salt affected saline soil than non saline soil.

Application of pesticides (Carbofuron and Phorate) increased the leaching losses of ammonical-N in the soil at each sampling period of rice as compared to pesticide untreated soil i.e. RDF alone irrespective of soil type.

Table 13: Leaching losses of nitrogen at different growth stages of rice crop as affected by various treatments (Year 2012)

Treatment	Nitrogen (mg pot ⁻¹)									Grand Total N loss	% N loss
	30 DAT			60 DAT			90DAT				
	NH ₄ ⁺ -N	NO ₃ ⁻ -N	Total N loss	NH ₄ ⁺ -N	NO ₃ ⁻ -N	Total N loss	NH ₄ ⁺ -N	NO ₃ ⁻ -N	Total N loss		
T ₁	38.48	19.52	58.00	30.96	15.12	46.08	27.79	12.17	39.95	144.03	21.67
T ₂	38.99	19.91	58.89	31.64	15.28	46.91	29.10	12.42	41.52	147.33	22.16
T ₃	39.22	20.14	59.35	31.73	15.37	47.10	29.31	12.53	41.84	148.29	22.31
T ₄	24.19	14.49	38.69	20.77	9.12	29.90	18.21	7.10	25.30	93.89	14.13
T ₅	24.93	14.93	39.86	21.15	9.35	30.51	18.25	7.27	25.52	95.88	14.43
T ₆	25.16	14.98	40.14	21.36	9.47	30.83	18.43	7.42	25.85	96.82	14.57
T ₇	9.49	7.95	17.44	9.00	5.71	14.71	5.39	3.33	8.72	40.88	6.15
T ₈	9.72	8.20	17.93	9.07	5.94	15.01	5.58	3.78	9.35	42.29	6.36
T ₉	9.84	8.23	18.06	9.16	6.04	15.20	5.67	3.96	9.63	42.89	6.45

SEm±	1.67	1.49		1.34	1.58		1.32	1.13			
CD@ 1%	4.82	4.30		3.86	4.55		3.81	3.25			

Table 14: Leaching losses of nitrogen at different growth stages of rice crop as affected by various treatments (Year 2013)

Treatment	Nitrogen (mg pot ⁻¹)									Grand Total N loss	% N loss
	30 DAT			60 DAT			90DAT				
	NH ₄ ⁺ -N	NO ₃ ⁻ -N	Total N loss	NH ₄ ⁺ -N	NO ₃ ⁻ -N	Total N loss	NH ₄ ⁺ -N	NO ₃ ⁻ -N	Total N loss		
T ₁	36.24	18.71	54.95	26.96	14.26	41.22	25.65	11.13	36.77	132.94	20.00
T ₂	37.60	19.26	56.86	28.48	14.49	42.97	25.85	11.44	37.29	137.12	20.63
T ₃	38.39	19.33	57.72	28.62	14.63	43.25	25.94	11.47	37.42	138.39	20.82
T ₄	31.57	10.76	42.33	24.12	7.63	31.75	18.48	7.19	25.67	99.75	15.01
T ₅	31.84	11.84	43.69	24.52	8.27	32.79	18.80	7.44	26.24	102.72	15.45
T ₆	31.94	12.42	44.35	24.70	8.47	33.17	18.96	7.67	26.64	104.16	15.67
T ₇	11.84	7.44	19.29	7.93	5.69	13.62	7.05	3.50	10.55	43.46	6.54
T ₈	12.05	7.81	19.86	8.16	5.71	13.87	7.19	3.48	10.67	44.40	6.68
T ₉	12.37	7.88	20.25	8.27	5.88	14.15	7.33	3.71	11.04	45.44	6.84
SEm±	1.56	1.43		1.75	1.28		1.60	1.08			
CD@ 1%	4.49	4.12		5.05	3.69		4.62	3.13			

This may be due to higher exchangeable ammonical-N content in pesticide treated soil than pesticide untreated soil. Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported that mineralization of N increased due to the application of insecticides in soil under rice crop. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils whereas Singh and Prasad (1991), reported that an increase in the amount of exchangeable $\text{NH}_4\text{-N}$ in pesticides treated soil attributed due to the stimulation of the growth and activities of ammonifying bacteria which were mainly responsible for mineralization of organic N and convert it into exchangeable ammonical-N form.

Among the pesticides, the treatments receiving Phorate recorded the high leaching losses of ammonical-N in soil at all the sampling interval of rice which were significantly superior over Carbofuron and RDF treated treatment irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in exchangeable $\text{NH}_4\text{-N}$ availability was more in case of Phorate as compared to Carbofuron due to stimulation was more pronounced with Phorate as compared to Carbofuron resulting in increased population sizes and activities of ammonifying bacteria which in turn influences the transformations of plant nutrient elements in soil and increasing its availability of exchangeable $\text{NH}_4\text{-N}$.

4.2.1.2 Nitrate-N (NO_3^- -N):

The data presented in Table 13 and 14 (Fig 1, 2, 3 , 5, 6 and 7) indicates that the leaching losses of nitrate - N from soil were observed to vary from 3.33 to 20.14 mg pot^{-1} and 3.50 to 19.33 mg pot^{-1} among the different treatments of rice in first and second year of experiment, respectively. It is also observed that the leaching losses of nitrate-N under various treatments were significantly influenced.

Leaching losses of nitrate-N from Lateritic soil pots under rice crop, varied from 19.52 to 20.14 mg pot^{-1} , 15.12 to 15.37 mg pot^{-1} and 12.17 to 12.53 mg pot^{-1} at 30, 60 and 90 DAT respectively during first year of experiment and in second year of experiment, its content varied from 18.71 to 19.33 mg pot^{-1} , 14.26 to 14.63 mg pot^{-1} and 11.13 to 11.47 mg pot^{-1} at 30, 60 and 90 DAT respectively. For Medium black soil, leaching losses of nitrate-N varied from 14.49 to 14.98 mg pot^{-1} , 9.12 to 9.47 mg pot^{-1} and 7.10 to 7.42 mg pot^{-1} at 30, 60 and 90 DAT respectively during first year of experiment and in second year of experiment, its content varied from 10.76 to 12.42 mg

pot⁻¹, 7.63 to 8.47 mg pot⁻¹ and 7.19 to 7.67 mg pot⁻¹ at 30, 60 and 90 DAT respectively. In Coastal saline soil, leaching losses of nitrate-N content varied from 7.95 to 8.23mg pot⁻¹, 5.71 to 6.04 mg pot⁻¹ and 3.33 to 3.96 mg pot⁻¹ in 30, 60 and 90 DAT respectively during first year of experiment while in second year of experiment, its content varied from 7.44 to 7.88 mg pot⁻¹, 5.69 to 5.88 mg pot⁻¹ and 3.50 to 3.71 mg pot⁻¹ at 30, 60 and 90 DAT respectively. The leaching losses of nitrate-N was found to be significantly superior in T₃ (Lateritic soil + RDF + Phorate) treatment however it was at par with T₁ and T₂ all the sampling periods in the both year of experiment.

The maximum leaching loss of nitrate-N occurred at 30 DAT periods and afterwards it showed declining trend gradually in subsequent observations and it was recorded minimum at 90 DAT in both the year of experiment irrespective of soil type. Santra *et al.*, (1994) reported that leaching loss of nitrate-N was highest during initial crop period days which declined as the period of submergence increases. This slow decline may be due to decreasing in concentration of nitrate-N in the soil solution resulting from the denitrification mechanism and also due to increased anaerobic condition with the progress of time minimizing the possibility of nitrification of NH₄-N in soil. The nitrification reaction stops at ammonical-N formation step in lowland paddy soil. Results also indicate that the relative magnitude of loss of nitrogen as NH₄-N is always higher than that of nitrate-N. The decrease in nitrate-N leaching loss during the growth period is results of nitrate-N being utilized by crop. The nitrate-N content in the leachate was maximum at 30 DAT due highest disintegration of aggregates, unclogged soil pores, limited utilization of applied N by the establishing rice seedlings and at a later stage markedly declined at 60 and 90 DAT due to higher root development and foraging capacity of plant. (Suresh *et al.*, 1994).

The total loss of nitrate-N over 90 days was observed maximum (6.63 to 7.23 percent of applied quantity) the Lateritic soil followed by Medium black soil (3.85 to 4.79 percent) and was minimum in Coastal saline soil (2.50 to 2.74 percent).

The data on nitrate-N leaching loss in various soil types found that maximum leaching loss of nitrate-N was seen in Lateritic soil followed by Medium black and Coastal saline soil. Lateritic soil is being light textured and low CEC and higher infiltration rate while favoured easy downward movement of of leachate as compared to other two soil types (Medium black and Coastal saline soil). (Purakayastha and Katyal 1998). The lowest value of nitrate-N in percolates of Coastal saline soil may be due to saline nature of this soil. Bandhopadyay and Bandhopadyay (1983) observed that the rate of mineralization of nitrogen was slowed down

by increase in soil salinity. The rate of conversion of one form of N to other form is quite slow in salt affected saline soil than non saline soil.

Application of pesticides (Carbofuron and Phorate) increased the leaching losses of nitrate -N in the soil at each sampling period of rice as compared to pesticide untreated soil i.e. RDF alone irrespective of soil type. This may be due to higher exchangeable nitrate -N content in pesticide treated soil than pesticide untreated soil. (Das and Mukherjee 2000a, b).

Among the pesticides, the treatments receiving Phorate recorded the highest leaching losses of nitrate-N in soil at all the sampling period of rice which were higher over Carbofuron and 100 percent RDF treated treatment irrespective of soil type. The Phorate was more effective than compared to Carbofuron in contributing to the higher value of exchangeable nitrate-N content irrespective of soil type. (Das and Mukherjee 1994).

4.2.1.3 Total N (Ammonical-N + Nitrate-N) leaching losses:

Total N leaching loss is the sum of ammonical-N + nitrate-N in leachate from soil under rice. The data presented in Table 13 and 14 (Fig 4 and 8). revealed that the leaching losses of total N from soil varied from 8.72 to 59.35 mg pot⁻¹ and 10.55 to 57.72 mg pot⁻¹ among the different treatments of rice in first and second year of experiment, respectively.

Leaching losses of total (Ammonical-N + Nitrate-N) N from rice growing pots having Lateritic soil, varied from 58.00 to 59.35 mg pot⁻¹, 46.08 to 47.10 mg pot⁻¹ and 39.95 to 41.84 mg pot⁻¹ at 30, 60 and 90 DAT respectively during first year of experiment however in second year of experiment, its content varied from 54.95 to 57.72 mg pot⁻¹, 41.22 to 43.25 mg pot⁻¹ and 36.77 to 37.42 mg pot⁻¹ at 30, 60 and 90 DAT respectively. In the Medium black soil, leaching losses of total (Ammonical-N + Nitrate-N) N varied from 38.69 to 40.14 mg pot⁻¹, 29.90 to 30.83 mg pot⁻¹ and 25.30 to 25.85 mg pot⁻¹ at 30, 60 and 90 DAT respectively during first year of experiment and in second year of experiment, its content varied from 42.33 to 44.35 mg pot⁻¹, 31.75 to 33.17 mg pot⁻¹ and 25.67 to 26.64 mg pot⁻¹ at 30, 60 and 90 DAT respectively. In Coastal saline soil leaching losses of total N varied from 17.44 to 18.06 mg pot⁻¹, 14.71 to 15.20 mg pot⁻¹ and 8.72 to 9.63 mg pot⁻¹ at 30, 60 and 90 DAT respectively during first year of experiment and in second year of experiment, its content varied from 19.29 to 20.25 mg pot⁻¹, 13.62 to 14.15 mg pot⁻¹ and 10.55 to 11.04 mg pot⁻¹ at 30, 60 and 90 DAT respectively. The leaching losses of total (Ammonical-N + Nitrate-N) N was found to be highest in T₃ (Lateritic soil + RDF + Phorate) treatment at all the sampling stages in the both years of experiment.

The cumulative total (Ammonical-N+Nitrate-N)-N leaching loss upto 90DAT was observed maximum (20.00 to 22.31percent of applied quantity) from the Lateritic soil followed by Medium black soil 14.13 to 15.67 percent) and minimum in Coastal saline soil (6.15 to 6.84 percent). The trend in leaching loss of total N showed a steady decrease from 30 to 90 DAT may be because of utilization of N by crop.

The leaching loss of total N observed higher in Lateritic soil treatment might be due to soil being a light textured soil with low CEC and higher infiltration rate favoured easy downward movement and leaching of applied nitrogen as compared to soil (Medium black and Coastal saline soil) having high CEC and low infiltration rate (Velu and Ramanathan 1998). The lowest value total N in percolates of Coastal saline soil over 90 days as compared to Lateritic and Medium black soil treatments were recorded in the present study. The lowest value of total N in percolates of Coastal saline soil may be due to saline nature, low infiltration rate and high CEC of this soil. Bandhopadyay and Bandhopadyay (1983) observed that the rate of mineralization of nitrogen was slowed down by increase in soil salinity. The rate of conversion of one form of N to other form is quite slow in salt affected saline soil than non saline soil.

Prasad *et al.*, (1986) observed that mineralization of N is controlled by water, temperature and aeration. Relative magnitude of different N loss mechanism will depend upon soil, weather, fertilizer and crop management. The higher Ammonical-N content in the leachate was because in wetland soil, very little amount of $\text{NH}_4\text{-N}$ is oxidized to $\text{NO}_3\text{-N}$ due to the reduced conditions and the mineralization of the fertilizer N proceeds up to the formation of $\text{NH}_4\text{-N}$ only (Suresh *et al.*, 1994).

Singh and Aulakh (2001) observed that as water logging increases, O_2 transport decreases & ammonification reaction increases because of the anaerobic nature. Santra *et al.* 1994 reported that less nitrate-N losses may be due to decreased in concentration of $\text{NO}_3\text{-N}$ in the soil solution resulting from the denitrification mechanism and also due the anaerobic condition with the progress of time minimizing the possibility of nitrification of $\text{NH}_4\text{-N}$ in soil.

4.2.2 Leaching losses of phosphorous at different growth stages of rice crop as affected by various treatments.

The data regarding the leaching losses of the phosphorous from soil at different growth stages (30, 60 and 90 DAT) of rice crop as influenced by various treatments is given in Table 15 (Fig 9 and 10) for two years of experiment.

Table 15. Leaching losses of phosphorous at different growth stages of rice crop as affected by various treatments.

Treatment	2012 ($\mu\text{g pot}^{-1}$)				% P loss	2013 ($\mu\text{g pot}^{-1}$)				% P loss
	30 DAT	60 DAT	90 DAT	Total loss		30 DAT	60 DAT	90 DAT	Total loss	
T ₁	4064.0	1936.0	1056.0	7056.0	3.16	3440.0	1504.0	816.0	5760.0	2.58
T ₂	4074.7	2000.0	1120.0	7194.7	3.22	3504.0	1536.0	880.0	5920.0	2.65
T ₃	4144.0	2032.0	1136.0	7312.0	3.28	3520.0	1541.3	896.0	5957.3	2.67
T ₄	2928.0	1509.3	816.0	5253.3	2.35	2768.0	954.7	784.0	4506.7	2.02
T ₅	2960.0	1552.0	848.0	5360.0	2.40	2816.0	976.0	832.0	4624.0	2.07
T ₆	3008.0	1584.0	912.0	5504.0	2.47	2848.0	992.0	848.0	4688.0	2.10
T ₇	1664.0	1312.0	736.0	3712.0	1.66	1280.0	688.0	656.0	2624.0	1.18
T ₈	1712.0	1344.0	768.0	3824.0	1.71	1312.0	704.0	688.0	2704.0	1.21
T ₉	1744.0	1360.0	784.0	3888.0	1.74	1392.0	736.0	704.0	2832.0	1.27
SEm ₊	0.67	0.26	0.24			0.28	0.26	0.34		
CD@ 1%	1.95	0.74	0.71			0.82	0.76	0.99		

The data revealed that the leaching losses of phosphorous from soil varied from 736.0 to 4144.0 $\mu\text{g pot}^{-1}$ and 656.0 to 3520.0 $\mu\text{g pot}^{-1}$ among the different treatments in first and second year of experiment, respectively. It is also observed that the leaching losses of phosphorous under various treatments were significantly influenced.

Leaching losses of phosphorous from rice growing pots having Lateritic soil, varied from 4064.0 to 4144.0 $\mu\text{g pot}^{-1}$, 1936.0 to 2032.0 $\mu\text{g pot}^{-1}$ and 1056.0 to 1136.0 $\mu\text{g pot}^{-1}$ at 30, 60 and 90 DAT respectively during first year of experiment while in second year of experiment, its content varied from 3440.0 to 3520.0 $\mu\text{g pot}^{-1}$, 1504.0 to 1541.3 $\mu\text{g pot}^{-1}$ and 816.0 to 896.0 $\mu\text{g pot}^{-1}$ in 30, 60 and 90 DAT respectively. For Medium black soil, leaching losses of phosphorous varied from 2928.0 to 3008.0 $\mu\text{g pot}^{-1}$, 1509.3 to 1584.0 $\mu\text{g pot}^{-1}$ and 816.0 to 912.0 $\mu\text{g pot}^{-1}$ at 30, 60 and 90 DAT respectively during first year of experiment while in second year of experiment, its content varied from 2768.0 to 2848.0 $\mu\text{g pot}^{-1}$, 954.0 to 992.0 $\mu\text{g pot}^{-1}$ and 784.0 to 848.0 $\mu\text{g pot}^{-1}$ in 30, 360 and 90 DAT respectively. In Coastal saline soil leaching losses of phosphorous varied from 1664.0 to 1744.0 $\mu\text{g pot}^{-1}$, 1312.0 to 1360.0 $\mu\text{g pot}^{-1}$ and 736.0 to 784.0 $\mu\text{g pot}^{-1}$ in 30, 60 and 90 DAT during first year of experiment and in second year of experiment, its content varied from 1280.0 to 1392.0 $\mu\text{g pot}^{-1}$, 688.0 to 736.0 $\mu\text{g pot}^{-1}$ and 656.0 to 704.0 $\mu\text{g pot}^{-1}$ at 30, 60 and 90 DAT. The leaching losses of phosphorous was found to be significantly superior in T₃ (Lateritic soil + RDF + Phorate) treatment at each sampling period in the both year of experiment.

In all soil types under study, the maximum leaching losses of phosphorous was observed at 30 DAT and it declined steadily during the crop growth upto 90 DAT. (Zhang *et al.* 2007) Sharma and Mishra (1988) also reported that the maximum leaching loss of phosphorous occurred at 30 DAT and afterwards it showed a declining trend. The higher leaching losses of phosphorous at 30 DAT sampling may be because of application of full dose of phosphorous as a basal dose to rice growing pots. Simard *et al.* (2000) reported that P leaching losses was found higher during the initial period and decreased thereafter. The minimum leaching losses of applied phosphorous at 90 DAT rice growing pot may be because of it is fixed by soil colloids or organic matter and other ions (Ca, Fe, Al and Mg) present in the soil.

Application of pesticides (Carbofuron and Phorate) increased the leaching losses of phosphorous content in the soil as compared to pesticide untreated soil. This may be due to higher availability of phosphorous in pesticide treated soil than pesticide untreated soil. (Das *et al.*, 2003).

Among the pesticides, the treatments receiving Phorate recorded the slightly higher leaching losses of phosphorous in soil over Carbofuron. This might be due to the Phorate was more effective than compared to Carbofuron in contributing to the higher value of available phosphorous content in soil.

The maximum percent in the leaching loss over 90 days was observed maximum (2.58 to 3.28 percent of applied quantity) in Lateritic soil followed by Medium black soil (2.02 to 2.47 percent) while it was minimum (1.18 to 1.74 percent) in Coastal saline soil.

The highest value of phosphorous in lechates of Lateritic soil are due to phosphorus adsorption is higher (CEC) and vermiculite content. The higher leaching losses of phosphorous in Lateritic soil may also be due to the soil being a light textured, low CEC and higher infiltration rate favoured easy downward movement and leaching of applied phosphorous as compared to Medium black soil having high CEC and low infiltration rate.

The total leaching loss of phosphorus over 90 day was found lowest in Coastal saline soil as compared to Lateritic and Medium black in the present study. The rate of leaching loss of phosphorous is minimum in Coastal saline soil because of saline nature of the soil and higher salts content than non saline soil. Muralidhar *et al.*, (1999). They further reported that as salinity increases the leaching losses of P decreases.

4.2.3 Leaching losses of potassium at different growth stages of rice crop as affected by various treatments.

The data regarding the leaching losses of the potassium from soil at different growth stages (30 DAT, 60 DAT and 90 DAT) of rice crop as influenced by various treatments is given in Table 16 for first and in Table 17 (Fig 11 and 12) for second year of the experiment.

The data reveals that the leaching losses of potassium from soil were observed to be vary from 7.90 to 66.11 mg pot⁻¹ and 9.16 to 60.90 mg pot⁻¹ among the different treatments of rice in first and second year of experiment, respectively. It is also observed from the data that the leaching losses of potassium under various treatments were significantly influenced.

Leaching losses of potassium from rice growing pots having Lateritic soil, varied from 29.16 to 29.70, 13.81 to 14.31 and 8.90 to 9.52 mg pot⁻¹ at 30, 60 and 90 DAT respectively during first year of experiment and in the second year of experiment, its content varied from 25.33 to 25.81, 18.32 to 18.68 and 11.44 to 12.04 mg pot⁻¹ in 30, 60 and 90 DAT respectively.

Table 16: Leaching losses of potassium at different growth stages of rice crop as affected by various treatments (2012).

Treatment	K (mg pot ⁻¹) 2012				% K loss
	30 DAT	60 DAT	90 DAT	Total loss	
T ₁	29.16	13.81	8.90	51.88	23.24
T ₂	29.40	14.07	9.16	52.63	23.58
T ₃	29.70	14.31	9.52	53.53	23.98
T ₄	18.44	13.35	7.90	39.70	17.79
T ₅	18.68	13.77	8.32	40.78	18.27
T ₆	19.04	14.01	8.50	41.56	18.62
T ₇	65.27	47.90	25.15	138.32	61.97
T ₈	65.75	48.08	25.57	139.40	62.46
T ₉	66.11	48.38	25.75	140.24	62.83
SEm±	1.02	1.15	1.29		
CD@ 1%	2.93	3.30	3.72		

Table 17: Leaching losses of potassium at different growth stages of rice crop as affected by various treatments (2013).

Treatment	K (mg pot ⁻¹)2013				% K loss
	30 DAT	60 DAT	90 DAT	Total loss	
T ₁	25.33	18.32	11.44	55.09	24.68
T ₂	25.63	18.50	11.68	55.81	25.00
T ₃	25.81	18.68	12.04	56.53	25.33
T ₄	15.81	12.81	8.86	37.49	16.79
T ₅	16.11	12.93	9.16	38.20	17.12
T ₆	16.29	13.17	9.40	38.86	17.41
T ₇	59.76	46.95	27.96	134.67	60.34
T ₈	60.66	47.43	28.08	136.17	61.01
T ₉	60.90	47.60	28.14	136.65	61.22
SEm±	1.04	1.12	0.90		
CD@ 1%	3.00	3.23	2.60		

Medium black soil, the leaching losses of potassium varied from 18.44 to 19.04, 13.35 to 14.01 and 7.90 to 8.50 mg pot⁻¹ at 30, 60 and 90 DAT period of sampling respectively during first year of experiment while in second year of experiment, its content varied from 15.81 to 16.29, 12.81 to 13.17 and 8.86 to 9.40 mg pot⁻¹ at 30, 60 and 90 DAT. In Coastal saline soil, leaching losses of potassium varied from 65.27 to 66.11, 47.90 to 48.38 and 25.15 to 25.75 mg pot⁻¹ at 30, 60 and 90 DAT respectively during first year of experiment however in second year of experiment, its content varied from 59.76 to 60.90, 46.95 to 47.60 and 27.96 to 28.14 mg pot⁻¹ at 30, 60 and 90 DAT respectively. The leaching losses of potassium was found to be significantly superior in T₉ (Coastal saline soil + RDF + Phorate) treatment at each sampling in the both year of experiment and was at par with T₈ and T₇ treatment.

During both the years the leaching losses of potassium steadily decreased from 0 to 90 days of the growth period of the crop. Similar Observations of declined potassium over the growth period of the crop were reported by Suresh *et al.*, (1993). It can be also observed that the leaching loss of potassium in pesticide treated soil to slightly higher than the untreated soil. This may be due to application of full dose of potassium as a basal dose. Karande (1985) also reported similar results. The potassium content in the leachate was highest at 30 DAT due to highest disintegration of aggregates, unclogged soil pores, limited utilization of applied K by the establishing rice seedlings, which then markedly declined during 60 and 90 DAT due to higher root development and foraging capacity of the crop. The higher level of losses in pesticide treated soils may be due to higher availability of potassium in pesticide treated soil

than pesticide untreated soil. The higher value of available potassium in pesticides treated soil was also reported by (Bagal 2009).

The leaching loss of potassium when compared to the different soil types reveals that maximum loss was observed in Coastal saline soils (60.34 to 62.83 percent of applied quantity) followed by Lateritic soil (23.24 to 25.33 percent) and was minimum in Medium black soil (16.79 to 18.62 percent). The higher leaching loss of potassium in Coastal saline soils may be due to higher native potassium content in the soil. The highest value of potassium in leachates of Coastal saline soil was also reported by Laxminarayana *et al.*, (1990). They further reported that the leaching losses of K from coastal soil column with treatment of potassium fertilizers through KCl and K₂SO₄ within 80 days were very high (35.5 and 53.3 percent of applied K) from KCl and K₂SO₄ respectively. The rate of leaching loss of K from coastal saline soil is several times higher than Lateritic soil and Medium black soil because of saline nature and rich in water soluble-K content than non saline soil. Being saline nature it contains potassium as major accumulated salts added through sea water (Joshi 1985). Similar observations were also recorded by (Mali 1989). The higher leaching losses of potassium in Lateritic soil might be due to soil being light textured with low CEC and higher infiltration which favoured easy downward movement of water and leaching of applied potassium as compared to Medium black soil which is having high CEC and low infiltration rate. Similar results were also reported by Sharply *et al.*, (1990) and Sreenivas *et al.*, (2008). The leaching loss of potassium were recorded less in Medium black as compared to Lateritic soil because the Medium black soil dominated by 2:1 type smectite clay minerals and red Lateritic soil dominated by Kaolinite type 1:1 type mineral as reported by Bajwa *et al.*, (1993) and Sharply *et al.*, (1990). They also recorded that within the different soils under study the total quantity of potassium leaching losses was found be more in Lateritic (Dapoli) soil as compared to (Medium black) neutral Karjat soil.

4.2.4 Leaching losses of pesticides at different growth stages of rice crop as affected by various treatments.

The data regarding the to the leaching losses of the pesticides from soil under rice crop at different growth stages at weekly interval upto 49 days were influenced by various treatments. However the analysed data of pesticide residues is presented in Table 18 and 19 (Fig 13, 14, 15 and 16) by combining the leachates of 0-28 and 29-42.

Table 18: Leaching losses of pesticides at different growth stages of rice crop as affected by various treatments. (2012)

Pesticides leaching losses	µg pot ⁻¹ (2012)							
	Lateritic		Medium black		Coastal saline		SEm±	C.D.
	PI	PII	PI	PII	PI	PII		
0-28DAT	3728.8	2914.03	2034	925.7	904.0	313.8	22.00	67.80
29-42 DAT	1866.3	1444.1	1010.6	460.6	453.1	154.7	6.12	18.88
Total loss	5595.1	4358.1	3044.6	1386.3	1357.1	468.6	22.51	69.36
% Loss	7.595	5.91	4.13	1.88	1.84	0.63		

PI: Carbofuron, PII: Phorate

Table 19: Leaching losses of pesticides at different growth stages of rice crop as affected by various treatments (2013).

Pesticides leaching losses	µg pot ⁻¹ (2013)							SEm±	C.D.
	Lateritic		Medium black		Coastal saline				
	PI	PII	PI	PII	PI	PII			
0-28DAT	2101.8	2062.0	1915.0	1055.7	748.2	477.2	14.93	46.0	
29-42DAT	1051.0	1031.7	957.9	528.8	372.4	239.4	4.59	14.1	
Total loss	3152.8	3093.7	2872.9	1584.5	1120.6	716.7	14.12	46.1	
% Loss	6.85	4.20	4.35	2.15	1.68	0.974			

PI: Carbofuron, PII: Phorate

The data reveals that the leaching losses of pesticides from soil were observed to be varied from 313.8 to 3728.8 $\mu\text{g pot}^{-1}$ and 154.7 to 1866.3 $\mu\text{g pot}^{-1}$ at 0-28 DAT and 29-42 DAT among the different treatments of rice in first year while in the second year of experiment, its content varied from 477.2 to 2101.8 and 239.4 to 1051.0 $\mu\text{g pot}^{-1}$ at 0-28 DAT and 29-42 DAT respectively. It is observed from the data that the leaching losses of pesticides under various treatments were significantly influenced.

Leaching losses of pesticides from rice growing pots having Lateritic soil, varied from 2914.03 to 3728.8 $\mu\text{g pot}^{-1}$ and 1444.1 to 1866.3 $\mu\text{g pot}^{-1}$ in 0-28, and 29-42 DAT respectively during first year of experiment and in second year of experiment, its content varied from 2062.0 to 2101.8 $\mu\text{g pot}^{-1}$ and 1031.7 to 1051.0 $\mu\text{g pot}^{-1}$ in 0-28 and 29-42 DAT respectively. In Medium black soil, leaching losses of pesticides varied from 925.7 to 2034.0 $\mu\text{g pot}^{-1}$ and 460.6 to 1010.6 $\mu\text{g pot}^{-1}$ in 0-28 and 29-42 DAT period of sampling respectively during first year of experiment and in second year of experiment, its content varied from 1055.7 to 1915.0 $\mu\text{g pot}^{-1}$ and 528.8 to 957.9 $\mu\text{g pot}^{-1}$ in 0-28 and 29-42 DAT. In Coastal saline soil, leaching losses of pesticides varied from 313.8 to 904.0 $\mu\text{g pot}^{-1}$ and 154.7 to 453.1 $\mu\text{g pot}^{-1}$ in 0-28 and 29-42 DAT respectively during first year of experiment and in second year of experiment, its content

varied from 477.2 $\mu\text{g pot}^{-1}$ to 748.2 and 372.4 to 239.4 $\mu\text{g pot}^{-1}$ in 0-28 and 29-42DAT respectively. The leaching losses of pesticides were found to be significantly superior in [Lateritic soil + RDF + PII (Carbofuron)] treatment at each sampling period in the both years of experiment.

The leaching losses of pesticides were maximum from 0-28 days irrespective of soil types. The trend in leaching loss of pesticides showed a decrease because of application of full dose of pesticides as a basal dose. Highest disintegration of aggregates, unclogged soil pores, limited utilization of applied pesticide by the establishing rice seedlings was the cause of maximum loss in 0-28 DAT which then markedly declined during 29-42 DAT due to higher root development and foraging capacity of plant.

The data indicated that, among the various soil types, the trend of per pot cumulative total pesticides leaching loss was found viz. Lateritic (4.20 to 7.59 percent) > Medium black (1.84 to 4.35 percent) > Coastal saline soil (0.63 to 1.84 percent). The leaching loss of pesticides was found maximum in Lateritic soil (4.20 to 7.59 percent) followed by Medium black soil (1.84 to 4.35 percent) and was lowest in Coastal saline soil (0.63 to 1.84 percent). The highest leaching losses of pesticides in Lateritic soil attributed for its low CEC and higher infiltration rate. Similar results were also reported by Parama *et al.*, (1991). Choudhary *et al.*, (2006) and Sundaram (1994) reported that the leaching losses pesticides amount was found higher from kaolintic clay minerals which are dominant in Lateritic soil as compared to smectitic clay which is dominant in Medium black and Coastal saline soil. The Coastal saline soil exhibited minimum leaching losses of pesticide because of its compact nature, high CEC, low infiltration rate and saline nature of soil.

Among the two pesticides when compared the leaching losses was higher in Carbofuron (1.84 to 7.59 percent) than Phorate (0.63 to 5.91 percent) because Carbofuron has higher solubility (320 mg liter^{-1}) in water than compared to Phorate (22 mg liter^{-1}). Sundaram (1994) and Paraíba *et al.*, (2007) reported that extent of leaching losses of pesticide is determined by the solubility, adsorptive properties and rate of degradation of the pesticide, as well as by the water movement in soil, and the physical and chemical characteristics of the soil.

In general, the cumulative total leaching loss of pesticides over 42 days was observed maximum (4.20 to 7.59 percent of applied quantity) from the Lateritic soil followed by Medium black soil (1.88 to 4.35 percent) while it was minimum (0.63 to 1.84 percent) in Coastal saline soil Nicosia *et al.*, (1990) reported the similar results.

Among the primary nutrients (N, P and K) the leaching losses of phosphorous in all soil types under study was found to be negligible as compared to nitrogen and potassium indicating immobility. Phosphorous is usually considered to be highly immobile in soils and its movement into the soil has generally been considered negligible because it is fixed by soil colloids, Organic matter and other ions which explains its minimum leaching loss than N and K.

The overall data regarding to the leaching losses of the N, P and pesticides from soil under rice crop as influences by various treatments showed trend viz. Lateritic soil > Medium black soil > Coastal saline soil and study indicated that these parameters were significantly affected due to pesticides treatments. However in case of potassium leaching losses from soil under rice crop as influences by various treatments showed trend Coastal saline soil > Lateritic soil > Medium black soil and study indicated that these parameters were significantly affected due to pesticides treatments.

4.3 Effect of different treatments on growth and yield of rice.

The growth parameters viz plant height, number of leaves, number of tillers, grain yield, straw yield and total biomass yield recorded during the two years of study indicated that these parameters were significantly affected due to various treatments.

4.3.1 Plant height (cm):

The data pertaining to the mean plant height at different growth stages (30, 60 DAT and at harvest stage) of Sahyadri-4 rice crop as influenced by various treatments is given in Table 20 for first and second year of experiment. The plant height of rice increased steadily with advancement of crop age. (Table 20)

Table 20: Effect of different treatments on plant height of rice during the growth period of rice crop

Treatment	Plant height (cm) 2012			Plant height (cm) 2013		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
T ₁	49.5	71.2	81.0	52.1	72.0	86.5
T ₂	54.1	75.5	84.4	57.7	76	89.9
T ₃	57.4	78.9	86.2	60.8	79.1	91.6
T ₄	55.8	81.0	92.1	61.4	79.9	92.4
T ₅	61.9	85.8	95.1	68.4	82.8	97
T ₆	64.6	88.2	98.1	71.4	85.3	100.7
T ₇	50.7	68.8	78.1	50.55	63.8	79.3
T ₈	54	71.3	80.6	54.1	66.6	8.0

T ₉	56.1	73.45	82.4	56.3	67.6	83.1
SEm±	1.36	1.42	1.37	1.53	1.80	1.86
CD @ 1%	2.85	3.0	2.89	3.22	3.92	3.93

The data reveals that the mean plant height of rice was observed to vary from 49.5 to 64.6 cm, 68.8 to 88.2 cm and 78.1 to 98.1 cm among the different treatments of rice at 30, 60 DAT and at harvest stage of rice respectively in first year of experiment while in the second year of experiment, it was observed to be varied from 50.55 to 71.4 cm, 63.8 to 85.3 cm and 79.3 to 100.7 cm among the different treatments of rice at 30, 60 DAT and at harvest stage of rice respectively.

In Lateritic soil, the mean plant height of rice, varied from 49.5 to 57.4 cm, 71.2 to 78.9 cm and 81 to 86.2 cm at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment while in second year of experiment, its content varied from 52.1 to 60.8 cm, 72 to 79.1 cm and 86.5 to 91.6 cm at 30, 60 DAT and at harvest stage of rice respectively. In Medium black soil, the mean plant height of rice varied from 55.8 to 64.6 cm, 81 to 88.2 cm and 92.1 to 98.1 cm at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment however in second year of experiment, its content varied from 61.4 to 71.4 cm, 79.9 to 85.3 cm and 92.4 to 100.7 cm at 30, 60 DAT and at harvest stage of rice respectively. In Coastal saline soil, the mean plant height of rice varied from 50.1 to 56.1 cm, 68.8 to 73.45 cm and 78.1 to 82.4 cm at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment while in second year of experiment, its content varied from 50.5 to 56.3 cm, 63.8 to 67.6 cm and 79.3 to 83.1 cm at 30, 60 DAT and at harvest stage of rice respectively. The mean plant height of rice was found to be significantly superior in T₆ (Medium black soil + RDF + Phorate) treatment at each sampling period in the both year of experiment which was at par with T₅ treatment. The enhancement in growth parameters in Medium black soil could be due to the better and proper nourishment of the crop when fertilized along with pesticides.

Application of pesticides (Carbofuron and Phorate) increased the mean plant height of rice in the soil at each sampling period of rice as compared to pesticide untreated soil i.e RDF alone in all the soil types under study. The higher level of available nutrient which caused an increase in the biomass and greater activity of beneficial microorganisms which increased net nutrient assimilation, including photosynthesis, of rice crop resulting in greater yield (Das *et al.*, 2003). Similar results were reported by Das and Mukherjee (1998b). They further reported that the higher

plant height of rice in pesticides treated treatment may be due to higher availability of nutrients in pesticide treated soil than pesticide untreated soil.

Among the pesticides, the treatments receiving Phorate recorded the highest mean plant height of rice in soil at all the sampling period of rice which were higher over Carbofuron. Similar results were quoted by Das and Mukherjee (2000a, b), Singh and Prasad (1991). Das and Mukherjee (1998b).

Among the various soil types, in the Medium black soil the maximum (55.8 to 100.7cm) plant height was attained followed by Lateritic soil (49.5 to 91.6cm) and found lowest (50.5 to 83.1cm) in Coastal saline soil. According to Patil (2001) a soil from Dapoli was Lateritic in nature, dominant in kaolinite clay mineral and had low fertility as compared to smectitic dominated (Medium black) soil.

The both of soil (Medium black and Coastal saline soil) under study are dominated by smectic clay minerals. However, the mean plant height of rice was found to be lowest in Coastal soil at each sampling period in the both years of experiment as compared to Lateritic and Medium black soil treatments. The lowest value the mean plant height of rice in Coastal saline soil salinity usually brings about stunted growth and low yield of crop may be due to increase in osmotic pressure and the toxicity of specific salts. Mahmood *et al.* (1999) conducted pot culture experiment and concluded that, the grain yield and yield contributing characteristics of rice varieties was reduced by 30 per cent with saline soil over the normal soils. Shereen *et al.* (2005) also reported that all yield contributing characters, tiller numbers, panicle number and panicle length were significantly reduced under salinity.

4.3.2 Number of leaves:

The data regarding to the mean number of leaves at different growth stages (30, 60 DAT and at harvest stage) of Sahyadri-4 rice crop as influenced by various treatments is given in Table 21 (Fig 17 and 18) for first and second year of experiment. The mean number of leaves of rice increased gradually with advancement of crop age.

The data reveals that the mean number of leaves of rice observed to be vary from to 15.5 to 36.3 , 34.7 to 67.4 and 36.9 to 76.9 among the different treatments of rice at 30, 60DAT and at harvest stage of rice respectively in first year of experiment while in second year of experiment it was observed to be vary from to 17.76 to 35.46, 34.9 to 64.7 and 38.36 to 79.6 among the different treatments of rice at 30, 60 DAT and at harvest stage of rice respectively.

Table 21: Effect of different treatments on number of leaves of rice during the growth period of rice crop.

Treatment	Number of leaves (2012)			Number of leaves (2013)		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
T ₁	21.7	40.6	45.6	25.3	39.1	44.2
T ₂	24.8	48.0	55.9	27.6	46.5	51.8
T ₃	25.8	48.8	58.9	28.9	48.1	54.4
T ₄	28.9	55.0	64.5	30.8	58.4	67.7
T ₅	35.2	65.7	73.3	34.4	62.4	78.9
T ₆	36.3	67.4	76.9	35.4	64.7	79.6
T ₇	15.5	34.7	36.9	17.7	34.9	38.3
T ₈	17.5	35.4	38.2	18.0	36.4	39.5
T ₉	19.1	35.8	39.7	19.9	37.5	40.0
SEm _±	1.20	1.53	1.67	1.44	1.38	1.58
CD @ 1%	2.53	3.22	3.52	3.02	2.90	3.33

In Lateritic soil, the mean number of leaves of rice, varied from 21.7 to 25.8, 40.6 to 48.8 and 45.6 to 58.9 at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment while in second year of experiment, its content varied from 25.3 to 28.9, 39.1 to 48.1 and 44.2 to 54.4 at 30, 60 DAT and at harvest stage of rice respectively. In Medium black soil, the mean number of leaves of rice varied from 28.9 to 36.3, 55.0 to 67.4 and 64.5 to 76.93 at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment while in second year of experiment, its content varied from 30.8 to 35.4, 58.4 to 64.7 and 67.7 to 79.6 at 30, 60 DAT and at harvest stage of rice respectively. In Coastal saline soil, the mean number of leaves of rice varied from 15.5 to 19.1, 34.7 to 35.8 and 36.9 to 39.7 at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment however in second year of experiment, its content varied from 17.7 to 19.9, 34.9 to 37.5 and 38.3 to 40.0 at 30, 60 DAT and at harvest stage of rice respectively. The mean number of leaves of rice was found to be significantly superior in T₆ (Medium black soil+ RDF+Phorate) treatment at each sampling period in the both years of experiment which was at par

with T₅ treatment. The maximum number of leaves in Medium black soil could be due to the better and proper nourishment of the crop.

Application of pesticides (Carbofuron and Phorate) increased the mean number of leaves of rice as compared to pesticide untreated soil irrespective of soil type. The numbers of leaves of the rice increased due to application of pesticides. Das *et al* (1998) observed that it could be due to the fact that insecticides might have protected the crop from harmful insect and allowed the plant to grow better with the resultant increase of microbial activities in the rhizosphere soil and such as enhancement of microbial activities which led to the increased availability of nutrients in the rhizosphere and thereby resulting in better growth and yield of crop. Singh and Prasad (1991), Das and Mukherjee (1998b) reported that mineralization of N and P increased due to the application of insecticides in soil under rice crop. Das *et al.* (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated yield and yield contributing character of rice.

Phorate treated soil recorded the high mean number of leaves on rice than Carbofuron. Das *et al.*, (2003) reported that Phorate was more effective than compared to Carbofuron in contributing to the higher value of availability of nutrients. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in availability of nutrients was also more in case of Phorate as compared to Carbofuron due to the stimulation was more pronounced with Phorate as compared to Carbofuron. They further reported that insecticide stimulation of both grain and straw yield and yield contributing characters was in order BHC> Phorate> Carbofuron

As regards the soil types are concerned the maximum number of leaves was observed in Medium black soil (28.97 to 79.6) followed by Lateritic soil (21.73 to 54.4) and found minimum in Coastal saline soil (15.53 to 40.0). The highest mean number of leaves was found in Medium black soil might be due to high fertility of this soil along with dominance of Smectitic clay minerals Patil (2001). They further reported that a soil from Dapoli was Lateritic in nature, dominant in Kaolinite clay mineral and had low fertility.

In spite of Smectic clay minerals present in coastal saline soil the number of leaves of rice was seen to be minimum as compared to Medium black soil might be due to the saline nature, low capacity of plant to assimilate essential nutrients from soil due to high osmotic pressure and high salt percent in the soil (Mahmood *et al.*, 1999). Shereen *et al.* (2005) also reported that all yield contributing characters like fertility, tiller numbers, panicle number and panicle length were significantly reduced under salinity.

4.3.3 Number of tillers

The data regarding to the mean number of tillers at different growth stages of rice (30, 60 DAT and at harvest stage) of rice crop (Sahyadri- 4) as influenced by various treatments is given in Table 22 for first and second year of experiment. The mean number of tillers of rice increased gradually with advancement of crop age Table 22 (Fig 19 and fig 20).

Table 22: Effect of different treatments on number of tillers of rice during the growth period of rice crop.

Treatment	Number of tillers (2012)			Number of tillers (2013)		
	30 DAT	60 DAT	At Harvest	30 DAT	60 DAT	At Harvest
T ₁	5.0	5.6	8.0	4.6	5.3	7.6
T ₂	5.6	7.6	9.3	5.3	7.0	9.0
T ₃	6.0	8.3	10.3	5.6	8.0	10.0
T ₄	6.3	9.6	10.3	6.0	9.3	10.6
T ₅	7.0	10.6	11.3	6.6	10.3	12.0
T ₆	7.3	11.0	12.0	7.0	11.0	12.6
T ₇	3.0	4.3	5.0	3.3	4.0	4.3
T ₈	3.3	4.6	5.6	3.6	4.6	5.0
T ₉	4.0	5.0	6.0	4.3	5.3	5.3
SEm±	0.56	0.60	0.58	0.41	0.47	0.44
CD@ 1%	1.19	1.40	1.23	0.87	0.99	0.93

The data reveals that the mean number of tillers of rice is observed to be vary from 3.00 to 7.33, 4.33 to 11.0 and 5.00 to 12.00 among the different treatments at 30, 60 DAT and at harvest in first year of experiment while it was observed to vary from 3.33 to 7.00, 4.00 to 11.0 and 4.33 to 12.66 among the different treatments at 30, 60 DAT and at harvest stage of rice in second year of experiment.

In Lateritic soil, the mean number of tillers of rice, varied from 5.00 to 6.00, 5.66 to 8.33 and 8.00 to 10.33 in at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment while in second year of experiment, its content varied from 4.66 to 5.66, 5.33 to 8.00 and 7.66 to 10.00 in at 30, 60 DAT and at harvest stage of rice respectively. In Medium black soil, the mean number of tillers of rice varied from 6.33 to 7.33, 9.66 to 11.0 and 10.33 to 12.00 at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment however in second year of experiment, its content varied from 6.00 to 7.00, 9.33

to 11.0 and 10.66 to 12.66 at 30, 60 DAT and at harvest stage of rice respectively. In Coastal saline soil the mean number of tillers of rice varied from 3.00 to 4.00, 4.33 to 5.00 and 5.00 to 6.00 at 30, 60 DAT and at harvest stage of rice respectively during first year of experiment while in second year of experiment, its content varied from 3.33 to 4.33, 4.00 to 5.33 and 4.33 to 5.33 at 30, 60 DAT and at harvest stage of rice. The mean number of tillers of rice was found to be significantly superior in T₆ (Medium black soil + RDF + Phorate) treatment at all stages in both the year of experiment which was at par with T₅ and T₆ treatment. The enhancement in growth parameters in Medium black soil could be due to the better and proper nourishment of the crop when fertilized along with pesticides or without pesticides.

Application of pesticides (Carbofuron and Phorate) increased the mean number of tillers of rice as compared to pesticide untreated soil. The decrease in mortality rate of tillers in pesticide treated soil over pesticide untreated treatment may be due to protection from insect and pest attack on rice crop. Abro *et al.* (2013) reported that the application of pesticides significantly increased the number of tillers by reducing the infestation by pest. Das and Mukherjee (2000 a, b), Singh and Prasad (1991), Das and Mukherjee (1998 b) reported that mineralization of N and P increased due to the application of insecticides in soil under rice crop. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils and increased yield and yield contributing character of rice.

The Phorate was more effective in producing more tillers than Carbofuron because Phorate was more effective in contributing to the higher value of availability of nutrients as well as reduction in mortality rate of tillers of rice irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in availability of nutrient content was more in case of Phorate as compared to Carbofuron.

The Medium black soil type yielded the maximum (6.00 to 12.66) number of tillers followed by Lateritic soil (4.66 to 10.33) and found minimum (3.33 to 6.00) in Coastal saline soil. The higher mean number of tillers in Medium black soil over Lateritic soil type might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Patil (2001) reported the similar results.

The Coastal soil recorded the lowest number of tillers might be due to its saline nature. Shereen *et al.* (2005) also reported that all yield contributing characters like fertility, tiller numbers, panicle number and panicle length were significantly reduced under salinity.

4.3.4 Effect of different treatments on yield of rice (Grain and straw)

The data regarding to the grain, straw yield and total (grain+straw) biomass yield of rice (Sahyadri-4) as influenced by various treatments in first and second year of experiment is presented in Table 23 and graphically represented in Fig. 21 and Fig. 22

4.3.4.1 Grain yield (g pot^{-1})

There were significant differences in grain yield of rice under different treatments studied. The data in Table 23 reveals that the grain yield of rice is observed to vary from 9.78 to 19.86 g pot^{-1} and 9.26 to 18.66 g pot^{-1} among the different treatments of rice in first year and second year of experiment respectively.

Table 23: Effect of different treatments on grain yield and straw yield of rice.

Treatment	2012 (g pot^{-1})			2013 (g pot^{-1})		
	Grain wt.	Straw wt.	Total	Grain wt.	Straw wt.	Total
T ₁	13.6	15.3	28.9	13.2	15.1	28.3
T ₂	15.1	17.9	33.0	14.8	17.2	32.0
T ₃	15.4	18.1	33.5	15.12	18.0	33.1
T ₄	18.8	21.1	39.9	17.8	22.8	40.6
T ₅	19.5	24.6	44.1	18.2	25.4	43.7
T ₆	19.8	25.0	44.9	18.6	25.6	44.3
T ₇	9.78	12.5	22.2	9.2	12.7	22.0
T ₈	10.1	13.0	23.1	9.9	13.4	23.3
T ₉	10.5	13.1	23.6	10.2	13.5	23.7
SEm _±	0.70	0.71		0.60	0.63	
CD@ 1%	1.47	1.51		1.26	1.32	

In Lateritic soil, the grain yield of rice, varied from 13.6 to 15.4 g pot^{-1} and 13.2 to 15.1 g pot^{-1} of rice during first year and second year of experiment respectively. In Medium black soil, the grain yield of rice varied from 18.8 to 19.8 g pot^{-1} and 17.8 to 18.6 g pot^{-1} during first year and second year experiment respectively. In Coastal saline soil, the grain yield of rice varied from 9.78 to 10.5 g pot^{-1} and 9.26 to 10.2 g pot^{-1} during first year of and second year of experiment respectively. The grain yield of rice was found to be significantly superior (19.8 g pot^{-1} in 2012 and 18.6 g pot^{-1} in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment in both the year of experiment which was at par with T₅ and T₄ treatment. The higher yield in Medium black soil could be due to the better and proper nourishment of the crop.

Application of pesticides (Carbofuron and Phorate) increased the grain yield of rice in the soil as compared to pesticide untreated soil. Das and Mukherjee (1998b) reported that the yields of the crop were increased due to application of pesticides. This may be due to higher availability of nutrients content in pesticide treated soil than pesticide untreated soil. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated yield and yield contributing character of rice. The treatments receiving Phorate recorded the highest the grain yield of rice which were higher over Carbofuron in all soil type. Similar results were quoted by Das *et al.*, (2003). They further reported that the insecticide stimulation of both grain and straw yield was in order BHC> Phorate> Carbofuron. (Das *et al.*, 1998)

The highest grain yield was recorded (17.8 to 19.8 g pot⁻¹) in Medium black followed by Lateritic soil (13.2 to 15.12 g pot⁻¹) and was lowest in Coastal saline soil (9.2 to 10.5 g pot⁻¹). The highest grain yield was observed in Medium black soil over Lateritic soil type might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were quoted by Patil (2001).

The grain yield of rice was recorded lowest in Coastal soil in the both year of experiment might be due to the saline nature. Salinity of Coastal saline soil is main cause for low yield of rice. Soil salinity is main cause for minimizing the yield of rice even after presence of essential available nutrients. The increased osmotic pressure and high salt content of Coastal saline soil leads to make the rice crop deficient even after higher available essential nutrients content in soil. Mahmood *et al.* (1999) conducted pot culture experiment and concluded that, the grain yield and yield contributing characteristics of rice varieties was reduced by 30 per cent with saline soil over the normal soils. Shereen *et al.* (2005) also reported that all yield contributing characters like fertility, tiller numbers, panicle number and panicle length were significantly reduced under salinity.

4.3.4.2 Straw yield (g pot⁻¹)

There were significant differences in straw yield of rice under different treatments studied. The data presented in Table 23 (Fig 22). reveals that the straw yield of rice was observed to be varying from 12.5 to 25.06 g pot⁻¹ and 12.79 to 25.63 g pot⁻¹ among the different treatments of rice at harvest in year 2012 and 2013 respectively.

In Lateritic soil, the straw yield of rice, varied from 15.33 to 18.16 g pot⁻¹ and 15.16 to 18.06 g pot⁻¹ during first year of and second year of experiment respectively. In Medium black soil, the straw yield of rice varied from 21.16 to 25.06 g

pot⁻¹ and 22.8 to 25.63 g pot⁻¹ during first year of and second year of experiment respectively. In Coastal saline soil, the straw yield of rice varied from 12.5 to 13.1 g pot⁻¹ and 12.79 to 13.55 g pot⁻¹ during first year and second year of experiment respectively. The straw yield of rice was found to be significantly superior (25.0 g pot⁻¹ in 2012 and 25.6 g pot⁻¹ in 2013) in T₆ (Medium black soil + RDF+ Phorate) treatment which was at par with T₅ treatment in the both year of experiment. The higher straw yield in Medium black soil could be due to the better and proper nourishment of the crop.

Application of pesticides (Carbofuron and Phorate) increased the straw yield of rice in the soil as compared to pesticide untreated soil i.e 100 per cent RDF alone irrespective of soil type. Das and Mukherjee (1998b) reported the similar results. This could be due to the fact that insecticide might have protected the crop from harmful insect as well as increase in availability of nutrients. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose increased yield and yield contributing character of rice. The treatments receiving Phorate recorded the highest the straw yield of rice which were higher over Carbofuron in all soil types. Similar results were quoted by Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003). The insecticide stimulation of both grain and straw yield was in order BHC> phorate> Carbofuron. Das and Mukherjee (1998b).

The straw yield of rice was found to be highest (21.1 to 25.6 g pot⁻¹) Medium black followed by Lateritic soil (15.3 to 18.1 g pot⁻¹) and minimum in Coastal saline soil (12.5 to 13.5 g pot⁻¹). The higher straw yield in Medium black soil treatment over Lateritic soil type might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were quoted by Patil (2001).

The Coastal soil was recorded lowest straw yield of rice in the both year of experiment might be due to the saline nature. Mahmood *et al.* (1999) conducted pot culture experiment and concluded that, the yield and yield contributing characteristics of rice varieties was reduced by 30 per cent with saline soil over the normal soils.

4.3.4.3 Total biomass yield of rice (g pot⁻¹):

There were significant differences in total biomass yield of rice under different treatments studied. The data presented in Table 23 reveals that the total biomass yield rice were observed to vary from 22.8 to 44.93 g pot⁻¹ and 22.06 to 44.3 g pot⁻¹ among the different treatments of rice in first year and second year of experiment respectively.

In Lateritic soil, the total biomass yield of rice, varied from 28.93 to 33.56 g pot⁻¹ and 28.36 to 33.18 g pot⁻¹ during first year and second year of experiment respectively. In Medium black soil, the total biomass yield of rice varied from 39.96 to 44.1 g pot⁻¹ and 40.6 to 44.3 g pot⁻¹ during first year of and second year of experiment respectively. In Coastal saline soil the total biomass yield of rice varied from 22.28 to 23.6 g pot⁻¹ and 22.06 to 23.75 g pot⁻¹ during first year and second year of experiment respectively. The increased in total yield of rice in Medium black soil could be due to the better and proper nourishment of the crop.

Application of pesticides (Carbofuron and Phorate) increased total biomass yield of rice in the soil as compared to pesticide untreated soil. Das and Mukherjee (1998b) reported the similar results. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose increased yield and yield contributing character of rice.

Among the pesticides, the treatments receiving Phorate recorded the high total biomass yield in rice over Carbofuron. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) reported the similar results. The insecticide stimulation of both grain and straw yield was in order BHC> Phorate> Carbofuron. Das and Mukherjee (1998b).

The data indicated that, among the various soil types, the total biomass yield of rice trend was found Medium black (39.9 to 44.9 g pot⁻¹) followed by Lateritic soil (28.3 to 33.5 g pot⁻¹) and minimum in Coastal saline soil (22.0 to 23.75 g pot⁻¹). The higher total biomass yield in Medium black soil treatment over Lateritic soil type might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were quoted by Patil (2001). The lowest total biomass yield of rice in Coastal saline soil might be due to the saline nature. Soil salinity is main cause for minimizing the yield of rice even after presence of essential available nutrients. The increased osmotic pressure and high salt content of Coastal saline soil leads to make the rice crop deficient and results into decreased net nutrient assimilation by rice plant even after higher available essential nutrients content in soil. Soil salinity usually brings about stunted growth and low yield of crop may be due to increase in osmotic pressure so soil water and by the toxicity of specific ions. Mahmood *et al.* (1999) conducted pot culture experiment and concluded that, the yield and yield contributing characteristics of rice varieties was reduced by 30 per cent with saline soil over the normal soils. Shereen *et al.* (2005) also reported that all yield contributing characters like fertility, tiller numbers, panicle number and panicle length were significantly reduced under salinity.

The data indicated that, among the various soil types, the yield of rice trend was found viz., Medium black > Lateritic soil > Coastal saline soil.

4.4 Effect of different treatments on nitrogen, phosphorous, potassium and uptake in grain and straw of rice at harvest stage.

4.4.1 Effect of different treatments on nitrogen, phosphorous, potassium and pesticide content in grain and straw of rice at harvest stage.

The data pertaining to the nutrient content in rice grain and straw affected due to different treatments is presented in Table.24 and 25. (Fig 23 and 24) The nutrient content viz nitrogen, phosphorous and potassium content in grain of rice recorded during the two years of study indicated that it was significantly affected due to various treatments.

4.4.1.1 Nitrogen content in grain:

The data regarding the N content of the grain of (Sahyadri-4) rice crop as affected by various treatments for 2012 and 2013 is discussed in Table 24.

Table.24: Effect of different treatments on Nitrogen, phosphorous and potassium content in grain of rice.

Treatment	2012 (%)			2013 (%)		
	Total N	Total P	Total K	Total N	Total P	Total K
T ₁	1.186	0.138	0.270	1.220	0.140	0.284
T ₂	1.196	0.142	0.272	1.260	0.154	0.285
T ₃	1.230	0.149	0.278	1.290	0.160	0.288
T ₄	1.383	0.152	0.243	1.420	0.184	0.232
T ₅	1.423	0.158	0.248	1.450	0.188	0.235
T ₆	1.463	0.162	0.249	1.460	0.192	0.238
T ₇	1.056	0.110	0.291	1.130	0.116	0.300
T ₈	1.083	0.125	0.294	1.150	0.119	0.302
T ₉	1.110	0.129	0.297	1.160	0.120	0.306
SEm±	0.032	0.013	0.012	0.023	0.008	0.010
CD@ 1%	0.069	0.027	0.025	0.049	0.018	0.039

The nitrogen content in grain of rice observed to be vary from 1.056 to 1.463 percent and 1.130 to 1.460 percent among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the nitrogen content in grain of rice, varied from 1.186 to 1.230 percent during first year of experiment and in second year of experiment, its

content varied from 1.220 to 1.290 percent. In Medium black soil, the nitrogen content in grain of rice varied from 1.383 to 1.463 percent and 1.420 to 1.460 percent during first year and in second year of experiment. In coastal saline soil, the nitrogen content in grain of rice varied from 1.056 to 1.110 percent, during first year of experiment and in second year of experiment, its content varied from 1.130 to 1.160 percent. The Nitrogen content in grain of rice was found to be significantly superior (1.463 and 1.460 percent in first and second year of experiment respectively) in T₆ (Medium black soil + RDF + Phorate) treatment in the both years of experiment which was at par with T₅ treatment.

Application of pesticides (Carbofuron and Phorate) increased the nitrogen content in grain of rice as compared to pesticide untreated soil. The higher level of available nutrient caused the increased net nutrient assimilation by grain. The higher availability of nutrients content in pesticide treated soil than pesticide untreated soil was reported by Das and Mukherjee (2000a, b), Singh and Prasad (1991). Das and Mukherjee (1998b) reported that mineralization of N increased due to the application of insecticides in soil under rice crop. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils and increased yield and yield contributing character of rice.

The nitrogen content in grain of rice was found maximum in Medium black (1.383 to 1.463 percent) followed by Lateritic soil (1.186 to 1.290 percent) and minimum in Coastal saline soil (1.056 to 1.160 percent). The higher nitrogen content in grain of rice from Medium black soil over Lateritic soil treatment might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were quoted by Patil (2001). The low nitrogen content in grain of rice from Lateritic soil was observed in present study due to low fertility of soil and dominance kaolinitic minerals. These results are in agreement with Patil (2001).

4.4.1.2 Phosphorous content in grain:

The data regarding to the phosphorous content in grain of rice (Sahyadri- 4) as influenced by various treatments is given in Table 24 (Fig 25 and 26).for 2012 and 2013.

The data reveals that the phosphorous content in grain of rice varied from 0.110 to 0.162 percent and 0.116 to 0.192 percent among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the phosphorous content in grain of rice, varied from 0.138 to 0.149 percent during first year while in second year of experiment, its content varied from 0.140 to 0.160 percent. In Medium black soil, the phosphorous content in grain of rice varied from 0.152 to 0.162 percent and 0.184 to 0.192 percent during first year and in second year of experiment respectively. In Coastal saline soil the phosphorous content in grain of rice varied from 0.110 to 0.129 percent during first year of experiment and in second year of experiment, its content varied from 0.116 to 0.120 percent. The phosphorous content in grain of rice was found to be significantly superior (0.162 and 0.192 percent in first and second year of experiment respectively) in T₆ (Medium black soil + RDF + Phorate) treatment in both the years of experiment, but in the first year it was found at par with T₁, T₂, T₃, T₄ and T₅ treatment while in the second year it was found at par with the T₄ and T₅ treatments.

The soil types, phosphorous content in grain of rice was found to be maximum in Medium black soil (0.152 to 0.192 percent) followed by Lateritic soil (0.138 to 0.160 percent) and were minimum in Coastal saline soil (0.110 to 0.129 percent). The higher phosphorous content in grain of rice in Medium black soil treatment over the other soil types is due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were reported by Patil (2001).

The Medium black and Coastal saline soils under study are dominated by smectitic clay minerals. However, the phosphorous content in grain of rice was found to be lowest in Coastal soil as compared to Medium black soil treatments. The lowest value the phosphorous content in grain of rice in Coastal saline soil than non saline is due to the saline nature. Soil salinity is main cause for minimizing the yield of rice even after presence of essential available nutrients. The increased osmotic pressure and high salt content of Coastal saline soil leads to make the rice crop deficient and results into decreased net nutrient assimilation by rice even when higher available essential nutrients are present in soil. Soil salinity usually brings about stunted growth and low yield of crop may be due to increase in osmotic pressure so soil water and by the toxicity of specific ions. Mahmood *et al.* (1999) conducted pot culture experiment and concluded that, the grain yield and yield contributing characteristics of rice varieties was reduced by 30 per cent with saline soil over the normal soils. Shereen *et al.* (2005) also reported that all yield contributing characters like fertility, tiller numbers, panicle number and panicle length were significantly reduced under salinity.

Application of pesticides (Carbofuron and Phorate) increased the phosphorous content in grain of rice as compared to pesticide untreated treatment because higher availability of nutrients in pesticide treated soil. Das and Mukherjee (2000a,b), Singh and

Prasad (1991). The higher level of available nutrient, caused in the increased net nutrient assimilation of nutrients by crop. Das and Mukherjee (1998b) reported that mineralization of P increased due to the application of insecticides in soil under rice crop.

The treatments receiving Phorate recorded the higher phosphorous content in grain which were higher than Carbofuron. This might be due to the Phorate was more effective than Carbofuron in contributing to the higher value of availability of phosphorous in soil. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also reported the higher available P in phorate treated soil.

4.4.1.3 Potassium content in grain:

The data of the potassium content in grain of rice (Sahyadri-4) as influenced by various treatments is given in Table 24 (Fig 27 and 28).for first and second year of experiment.

The data shows that the potassium content in grain of rice varied from 0.243 to 0.297 percent and 0.232 to 0.192 percent among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the potassium content in grain of rice, varied from 0.270 to 0.278 percent during first year of experiment while in second year of experiment, its content varied from 0.280 to 0.288 percent. In Medium black soil, the potassium content in grain of rice varied from 0.243 to 0.249 percent and 0.232 to 0.238 percent during first year of experiment and in second year of experiment. In coastal saline soil the potassium content in grain of rice varied from 0.291 to 0.297 percent, during first year of experiment and in second year of experiment, its content varied from 0.300 to 0.306 percent,. The potassium content in grain of rice was found to be significantly superior (0.297 percent in first year and 0.306 percent in second year of experiment) in T₉ (Coastal saline soil + RDF + Phorate) treatment in both years of experiment but in the first year it was found at par with T₂, T₃, T₇ and T₈ treatment while in the second year it was found at par with T₁, T₂, T₃, T₇ and T₈ treatments.

Among the various soil types, the maximum potassium content in grain was found in Coastal saline soil (0.291 to 0.306 percent) followed by Lateritic (0.270 to 0.288 percent) and was minimum in Medium black soil (0.232 to 0.249 percent). The application of pesticides (Carbofuron and Phorate) increased the potassium content in grain of rice in the soil as compared to pesticide untreated soil. The Phorate pesticide was more effective than compared to Carbofuron in contributing to the higher value of potassium content in grain.

4.4.1.4 Effect of different treatments on Nitrogen, phosphorous and potassium content in straw of rice at harvest stage.

The nutrient content of major nutrients, nitrogen, phosphorous and potassium content in straw of rice at harvest stage is discussed for two years study under different sub heading. (Table 25)

4.4.1.4.1 Nitrogen content in straw:

The data regarding to the nitrogen content in rice straw of (Sahyadri-4) as influences by various treatments is given in Table 25 for first and second year of experiment.

Table 25. Effect of different treatments on nitrogen, phosphorous and potassium content in straw of rice.

Treatment	2012 (%)			2013 (%)		
	Total N	Total P	Total K	Total N	Total P	Total K
T ₁	0.73	0.182	1.817	0.75	0.173	1.703
T ₂	0.79	0.189	1.833	0.78	0.182	1.736
T ₃	0.81	0.194	1.857	0.79	0.189	1.743
T ₄	0.86	0.207	1.541	0.91	0.219	1.570
T ₅	0.91	0.220	1.546	0.96	0.228	1.572
T ₆	0.92	0.243	1.549	0.99	0.231	1.576
T ₇	0.61	0.150	1.727	0.64	0.148	1.690
T ₈	0.68	0.169	1.742	0.68	0.159	1.699
T ₉	0.70	0.174	1.746	0.69	0.163	1.709
SEm±	0.035	0.017	0.020	0.026	0.010	0.023
CD@ 1%	0.074	0.037	0.032	0.056	0.021	0.071

The data presented in Table 25 reveals that the nitrogen content in straw of rice is observed to be vary from 0.61 to 0.92 percent and 0.64 to 0.99 percent in first and second year of experiment respectively.

In Lateritic soil, the nitrogen content in straw of rice, varied from 0.73 to 0.81 percent during first year of experiment while in second year of experiment, its content varied from 0.75 to 0.79 percent. In Medium black soil, the nitrogen content in straw of rice varied from 0.86 to 0.92 percent and 0.91 to 0.99 percent during first year of experiment while in second year of experiment respectively. In coastal saline soil, the nitrogen content in straw of rice

varied from 0.61 to 0.70 percent, during first year of experiment and in second year of experiment, its content varied from 0.64 to 0.69 percent. The nitrogen content in straw of rice was found to be significantly superior (0.92 and 0.99 percent in first and second year of experiment respectively) in T₆ (Medium black soil + RDF + Phorate) treatment in the both years of experiment which was at par with T₅ and T₆ treatment.

Among the different soil types, nitrogen content in straw was found maximum in Medium black (0.86 to 0.99 percent) followed by Lateritic soil (0.73 to 0.81 percent) and was minimum in Coastal saline soil (0.61 to 0.70 percent). The higher nitrogen content in straw in Medium black soil treatment over Lateritic soil type might be due to high fertility of this soil along with dominance of smectitic clay minerals. Similar results were quoted by Patil (2001). Coastal saline soil showed the lowest nitrogen content in straw. As salinity usually brings about stunted growth and low yield of crop due to increase in osmotic pressure and thereby by the toxicity of specific ions.

4.4.1.4.2 Phosphorous content in straw:

The data regarding to the phosphorous content in straw of (Sahyadri-4) rice as influenced by various treatments are given in Table 25 for 2012 and 2013.

The data reveals that the phosphorous content in straw of rice was observed to be varied from 0.150 to 0.243 percent and 0.148 to 0.231 percent among the different treatments of rice at harvest stage of rice in first and second year of experiment respectively.

In Lateritic soil, the phosphorous content in straw of rice, varied from 0.182 to 0.194 percent during first year of experiment while in second year of experiment, its content varied from 0.173 to 0.189 percent. In Medium black soil, the Phosphorous content in straw of rice varied from 0.207 to 0.243 percent and 0.219 to 0.231 percent during first year of experiment and in second year of experiment respectively. In Coastal saline soil, the phosphorous content in straw of rice varied from 0.150 to 0.174 percent, during first year of experiment while in second year of experiment, its content varied from 0.148 to 0.163 percent. The phosphorous content in straw of rice was found to be significantly superior (0.243 percent in 2012 and 0.231 percent in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment which was found at par with T₄ and T₅ treatment in the both year experiments.

The soil types, the phosphorous content in straw was found to be maximum in Medium black (0.207 to 0.243 percent) followed by Lateritic soil (0.173 to 0.194 percent) and was minimum in Coastal saline soil (0.148 to 0.174 percent). The higher phosphorous content

in straw in Medium black soil treatment might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were reported by Patil (2001).

The Medium black and Coastal saline soil under study are dominated by smectitic clay minerals. However, the phosphorous content in straw of rice was found to be lowest in Coastal saline soil in the both year of experiment as compared to Medium black soil treatments. Application of pesticides (Carbofuron and Phorate) increased the phosphorous content in straw of rice as compared to pesticide untreated soil. This may be due to higher availability of nutrients content in pesticide treated soil than pesticide untreated soil. Das and Mukherjee (2000a, b), Singh and Prasad (1991).

4.4.1.4.3 Potassium content in straw:

The data regarding to the potassium content in straw rice (Sahyadri-4) as influences by various treatments are given in Table 25..

The data reveals that the potassium content in straw of rice were observed to be varied from 1.541 to 1.857 percent and 1.570 to 1.743 percent among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the potassium content in straw of rice, varied from 1.817 to 1.857 percent during first year of experiment and in second year of experiment, its content varied from 1.703 to 1.743 percent. In Medium black soil, the potassium content in straw of rice varied from 1.541 to 1.549 percent and 1.570 to 1.576 percent during first year of experiment and in second year of experiment. In Coastal saline soil, the potassium content in straw of rice varied from 1.727 to 1.746 percent, during first year of experiment while in second year of experiment, its content varied from 1.690 to 1.709 percent. The potassium content in straw of rice was found to be significantly superior (1.857 and 1.743 percent in 2012 and 2013) in T₃ (Lateritic soil+RDF + Phorate) treatment in the both year of experiment but in the first year it was found at par with T₂ and T₁ treatment while in the second year it was found at par with T₁, T₂, T₈, T₇ and T₉ treatments.

Among the various soil types, potassium content in straw was found to be maximum in Lateritic (1.703 to 1.857 percent) followed by Coastal saline soil (1.690 to 1.746 percent) and was minimum in Medium black soil (1.541 to 1.576 percent). The potassium content in straw was found lower in Medium black soil treatment over Lateritic soil type in the present study. Similar results were reported by Patil (2001).

4.4.2 Effect of different treatments on Nitrogen, phosphorous and potassium uptake in rice.

The nutrient uptake of major nutrients, nitrogen, phosphorous and potassium in by grain, straw and total (grain N uptake + straw N uptake) of rice recorded during the

4.4.2.1 Nitrogen uptake

4.4.2.1.1 Nitrogen uptake in grain:

The data regarding to the nitrogen uptake by grain of rice (Sahyadri-4) as influenced by various treatments are given in Table 26 (Fig 23 and 24) for first and second year of experiment and discussed below.

Table 26: Effect of different treatments on uptake of nitrogen by grain and straw of rice crop

Treatment	2012 (mg kg ⁻¹)			2013 (mg kg ⁻¹)		
	Grain N uptake	Straw N uptake	Total N uptake	Grain N uptake	Straw N uptake	Total N uptake
T ₁	161.7	111.8	273.6	160.6	114.4	275.1
T ₂	181.5	125.7	307.2	185.9	136.7	322.7
T ₃	189.2	149.7	338.9	195.1	145.1	340.2
T ₄	260.1	184.8	445.0	252.6	206.6	459.3
T ₅	277.7	224.4	502.1	264.2	243.6	507.8
T ₆	290.4	231.0	521.5	271.8	253.2	525.1
T ₇	102.6	75.8	178.4	104.9	81.9	186.8
T ₈	110.1	89.2	199.3	113.4	90.6	204.0
T ₉	115.0	91.6	206.7	119.6	93.9	213.6
SEm _±	9.31	8.79	10.81	5.59	6.22	8.53
CD@ 1%	26.80	25.32	31.13	16.09	17.93	24.56

The data reveals that the nitrogen uptake by grain of rice observed to be vary from to 102.6 to 290.4 mg kg⁻¹ and 104.9 to 271.8 mg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively.

The nitrogen uptake in Lateritic soil by grain of rice, varied from 161.7 to 189.2 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 160.6 to 195.1 mg kg⁻¹. In Medium black soil, the nitrogen uptake by grain of rice varied from 260.1 to 290.4 mg kg⁻¹ and 252.6 to 271.8 mg kg⁻¹ during first year and in second year of

experiment respectively. In Coastal saline soil, the nitrogen uptake by grain of rice varied from 102.6 to 115.0 mgkg⁻¹ during first year of experiment while in second year of experiment, its content varied from 104.9 to 119.6 mg kg⁻¹. The nitrogen uptake by grain of rice was found to be significantly superior (290.4 and 271.8 mgkg⁻¹ in first and second year of experiment respectively) in T₆ (Medium black soil + RDF + Phorate) treatment in the both year of experiment which was at par with T₅ treatment.

Among the various soil types, the nitrogen uptake by grain was found to be maximum in Medium black (252.6 to 290.4 mg kg⁻¹) followed by Lateritic soil (160.6 to 195.1 mg kg⁻¹) and was minimum Coastal saline soil (102.6 to 119.6 mg kg⁻¹).

The higher nitrogen uptake by grain in Medium black soil might be due to high fertility of this soil along with dominance of smectitic clay minerals. Patil (2001)

Application of pesticides (Carbofuron and Phorate) increased the nitrogen uptake by grain of rice as compared to pesticide untreated soil. This may be due to higher availability of nutrients content in pesticide treated soil than pesticide untreated soil. Das and Mukherjee (2000a, b), Singh and Prasad (1991). Das and Mukherjee (1998b) reported that mineralization of N increased due to the application of insecticides in soil under rice crop. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils and increased yield and yield contributing character of rice.

Among the pesticides, the treatments receiving Phorate recorded the highest nitrogen uptake by grain of rice which was higher over Carbofuron and RDF treated treatment irrespective of soil type. This might be due to the Phorate was more effective than compared to Carbofuron in contributing to the higher value of availability of nutrients content irrespective of soil type.

4.4.2.1.2 Nitrogen uptake in straw:

The data regarding the nitrogen uptake by straw at harvest stage of (Sahyadri-4) rice crop as influence by various treatments is given in Table 26 (Fig. 23 and Fig 24) for first and second year of experiment and discussed below.

The data reveals that the nitrogen uptake by straw of rice were observed to be vary from 75.8 to 231.0 mg kg⁻¹ and 81.9 to 253.2 mg kg⁻¹ among the different treatments of rice at harvest stage of rice in first and second year of experiment respectively.

The nitrogen uptake in Lateritic soil, by straw of rice, varied from 111.8 to 149.7 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 114.4 to 145.1 mg kg⁻¹. In Medium black soil, the nitrogen uptake by straw of rice varied from 184.8 to 231.0 mg kg⁻¹ and 206.6 to 253.2 mg kg⁻¹ during first year and in second year of experiment respectively. In coastal saline soil the nitrogen uptake by straw of rice varied from 75.8 to 91.6 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 81.9 to 93.9 mg kg⁻¹. The nitrogen uptake by straw of rice was found to be significantly superior (231.0 mg kg⁻¹ and 253.2 mg kg⁻¹ in first and second year of experiment respectively) in T₆ (Medium black soil + RDF + Phorate) treatment which was at par with T₅ treatment in the both year of experiment.

Among the various soil types studied, the nitrogen uptake by straw was found to be maximum in Medium black (184.8 to 253.2 mg kg⁻¹) followed by Lateritic soil (111.4 to 149.7 mg kg⁻¹) and was minimum in Coastal saline soil (75.8 to 93.9 mg kg⁻¹).

The higher nitrogen uptake by straw in Medium black soil might be due to high fertility of this soil along with dominance of smectitic clay minerals. Similar results were quoted by Patil (2001). The nitrogen uptake by straw of rice was found to be lowest in Coastal soil in the both year of experiment might be due to the saline nature.

Application of pesticides (Carbofuron and Phorate) increased the nitrogen uptake by straw of rice as compared to pesticide untreated soil. This may be due to higher availability of nitrogen content in pesticide treated soil than pesticide untreated soil. Das and Mukherjee (2000a, b).

4.4.2.1.3 Nitrogen uptake by total biomass of Rice:

The data regarding to the nitrogen uptake in total biomass of rice crop as influences by various treatments is given in Table 26 for first and second year of experiment and discussed below.

The data reveals that the nitrogen uptake in total biomass of rice was observed to be vary from to 178.4 to 521.5 mg kg⁻¹ and 186.8 to 525.1 mg kg⁻¹ among the different treatments in first and second year of experiment respectively.

The nitrogen uptake in Lateritic soil by total biomass of rice, varied from 273.6 to 338.9 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 275.1 to 340.2 mg kg⁻¹. In Medium black soil, the nitrogen uptake in total biomass of Rice varied from 445.0 to 521.5 mg kg⁻¹ and 459.3 to 525.1 mg kg⁻¹ during first year of

experiment and in second year of experiment respectively. In Coastal saline soil, the nitrogen uptake in total biomass of rice varied from 178.4 to 206.7 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 186.8 to 213.6 mg kg⁻¹. The nitrogen uptake in total biomass of rice was found to be significantly superior (521.5 mg kg⁻¹ in 2012 and 525.1 mg kg⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment which was at par with T₅ treatment in the both year of experiment.

Among the various soil types, the nitrogen uptake in total biomass of rice was found to be maximum in Medium black soil (445.0 to 525.1 mg kg⁻¹) followed Lateritic soil (273.6 to 340.2 mg kg⁻¹) and was minimum in Coastal saline soil (178.4 to 213.6 mg kg⁻¹). The higher nitrogen uptake by total biomass of rice in Medium black soil might be due to high fertility of this soil along with dominance of smectitic clay minerals. Similar results were quoted by Patil (2001).

Application of pesticides (Carbofuron and Phorate) increased the nitrogen uptake in total biomass of rice in the soil as compared to pesticide untreated soil. This may be due to higher availability of nutrients content in pesticide treated soil than pesticide untreated soil. Das and Mukherjee (2000a,b), Singh and Prasad (1991).

Among the pesticides, the treatments receiving Phorate recorded the higher nitrogen uptake in total biomass which was higher over Carbofuron. This might be due to the Phorate was more effective than compared to Carbofuron in contributing to the higher value of availability of nutrients content irrespective of soil type. (Das and Mukherjee 1994).

4.4.2.2 Phosphorous uptake by grain and straw of rice

The data regarding to the uptake of phosphorous by grain and straw (Sahyadri-4) rice crop as influences by various treatments are given in Table 8 for first and second year of experiment and discussed below. (Table 27). The effect of application of RDF with or without pesticides in different types of soil was observed to be positive and statistically significant.

4.4.2.2.1 Phosphorous uptake in grain:

The data regarding to the phosphorous uptake in grain rice (Sahyadri-4) as influenced by various treatments is given in Table 27 (Fig 25 and 26) for first and second year of experiment and discussed below.

Table 27: Effect of different treatments on uptake of phosphorous by grain and straw of rice crop

Treatment	2012 (mg kg ⁻¹)	2013 (mg kg ⁻¹)
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	Grain uptake	Straw uptake	Total uptake	Grain uptake	Straw uptake	Total uptake
T ₁	18.30	28.00	46.36	18.58	26.34	44.93
T ₂	21.36	33.98	55.34	22.82	31.42	54.24
T ₃	22.70	35.34	58.05	24.31	34.02	58.33
T ₄	28.62	43.69	72.31	32.79	49.87	82.67
T ₅	30.84	54.01	84.86	34.30	56.87	91.17
T ₆	31.78	61.09	92.87	35.94	59.23	95.18
T ₇	10.72	18.84	29.56	10.85	19.02	29.87
T ₈	12.88	22.05	34.93	11.81	21.34	33.16
T ₉	13.41	22.89	36.31	12.21	22.17	34.38
SEm _±	1.96	3.36	3.99	1.29	2.15	2.73
CD@ 1%	5.64	9.67	11.51	3.74	6.20	7.85

The data reveals that the phosphorous uptake in grain of rice is observed to be vary from to 10.72 to 31.78 mg kg⁻¹ and 10.85 to 35.94 mg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the phosphorous uptake in grain of rice, varied from 18.3 to 22.7 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 18.58 to 24.31 mg kg⁻¹. In Medium black soil, the phosphorous uptake in grain of rice varied from 28.62 to 31.78 mg kg⁻¹ and 32.79 to 35.94 mg kg⁻¹ during first year of experiment and in second year of experiment respectively. In Coastal saline soil the phosphorous uptake in grain of rice varied from 10.72 to 13.41 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 10.85 to 12.21 mg kg⁻¹. The phosphorous uptake in grain of rice was found to be significantly superior (35.94 mg kg⁻¹ in 2012 and 31.78 mg kg⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment which was at par with T₅ and T₄ treatment in the both year of experiment.

Among the various soil types, the phosphorous uptake in grain was found to be maximum in Medium black (28.62 to 35.94 mg kg⁻¹) followed by Lateritic soil (18.3 to 24.31 mg kg⁻¹) and was minimum in Coastal saline soil (10.85 to 13.41 mg kg⁻¹). The higher phosphorous uptake in grain in Medium black soil treatment might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were quoted by Patil (2001).

Application of pesticides (Carbofuron and Phorate) increased the phosphorous uptake in grain of rice as compared to pesticide untreated soil irrespective of soil type. This may be due to higher availability of nutrients content in pesticide treated soil than pesticide untreated soil.

Among the pesticides, the treatments receiving Phorate recorded the higher the total phosphorous uptake in grain which were higher over Carbofuron might be due to the phorate was more effective than compared to Carbofuron in contributing to the higher value of availability of nutrients content irrespective of soil type .

4.4.2.2.2 Phosphorous uptake by rice straw:

The data regarding to the phosphorous uptake by straw of (Sahyadri-4) rice crop as influenced by various treatments is given in Table 27 for first and second year of experiment and discussed below.

The data reveals that the phosphorous uptake by straw of rice were observed to be vary from 18.84 to 61.09 mg kg⁻¹ and 19.02 to 59.23 mg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the phosphorous uptake by straw of rice, varied from 28.00 to 35.34 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 26.34 to 34.02 mg kg⁻¹. In Medium black soil, the phosphorous uptake by straw of rice varied from 43.69 to 61.09 mg kg⁻¹ and 49.87 to 59.23 mg kg⁻¹ during first year of experiment and in second year of experiment. In Coastal saline soil the phosphorous uptake by straw of rice varied from 18.84 to 22.89 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 19.02 to 22.17 mg kg⁻¹. The phosphorous uptake by straw of rice was found to be significantly superior (61.05 mg kg⁻¹ in 2012 and 59.23 mg kg⁻¹ in 2013) in T₆ (Medium black soil+ RDF + Phorate) treatment in the both year of experiment which was found at par T₅ treatments.

Among the various soil types, the phosphorous uptake by straw was found to be maximum in Medium black (43.69 to 61.09 mg kg⁻¹) soil followed by Lateritic soil (26.34 to 35.34 mg kg⁻¹) and was minimum in Coastal saline soil (18.84 to 22.89 mg kg⁻¹). The higher phosphorous uptake by straw in Medium black soil treatment might be due to high fertility of this soil along with dominance of Smectitic clay minerals. Similar results were reported by Patil (2001). The phosphorous uptake by straw of rice was found to be lowest in Coastal soil in the both year of experiment might be due to the saline nature.

Among the pesticides, the treatments receiving Phorate recorded the highest phosphorous uptake by straw which were higher over Carbofuron. This might be due to the Phorate which was more effective than compared to Carbofuron in contributing to the higher value of availability of nutrients content irrespective of soil type. Das *et al.*, (2003) also

showed that the increased in availability of nutrients content was more in case of Phorate as compared to Carbofuron.

4.4.2.2.3 Phosphorous uptake by total biomass rice:

The data regarding to the phosphorous uptake by total biomass of rice (Sahyadri-4) rice crop as influenced by various treatments is given in Table 27 for first and second year of experiment and discussed below.

The data reveals that the phosphorous uptake by total biomass of rice was observed to be varied from 29.56 to 92.87 mg kg⁻¹ and 29.87 to 95.18 mg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the phosphorous uptake by total biomass of rice, varied from 46.36 to 58.05 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 44.93 to 58.33 mg kg⁻¹. In Medium black soil, the phosphorous uptake by total biomass rice varied from 72.31 to 92.87 mg kg⁻¹ and 82.67 to 95.18 mg kg⁻¹ during first year and in second year of experiment respectively. In coastal saline soil, the phosphorous uptake by total biomass rice varied from 29.56 to 36.31 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 29.87 to 34.38 mg kg⁻¹. The phosphorous uptake by total biomass of rice was found to be significantly superior (92.87 mg kg⁻¹ in 2012 and 95.18 mg kg⁻¹ in 2013) in T₆ (Medium black soil+ RDF + Phorate) treatment which was at par with T₅ treatment in both the year of experiments.

Among the various soil types, the phosphorous uptake by total biomass rice was found to be maximum in Medium black (72.31 to 95.18 mg kg⁻¹) followed by Lateritic soil (44.93 to 58.33 mg kg⁻¹) and was minimum in Coastal saline soil (29.56 to 36.31 mg kg⁻¹). The higher phosphorous uptake by total biomass of rice in Medium black soil treatment might be due to high fertility of this soil along with dominance of Smectitic clay minerals. The phosphorous uptake by total biomass of rice was found to be lowest in Coastal soil in the both year of experiment might be due to the saline nature.

Application of pesticides (Carbofuron and Phorate) increased the phosphorous uptake by total biomass of rice as compared to pesticide untreated soil may be due to higher availability of nutrient content in pesticide treated soil than pesticide untreated soil. Das and Mukherjee (2000a,b), Singh and Prasad (1991). Das and Mukherjee (1998b) reported that mineralization of N and P increased due to the application of insecticides in soil under rice crop.

Among the pesticides, the treatments receiving Phorate recorded highest phosphorous uptake by total biomass of rice which were higher over Carbofuron might be due to the Phorate was more effective than compared to Carbofuron in contributing to the higher value of availability of nutrients content irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that availability of nutrient content was more in case of Phorate as compared to Carbofuron.

4.4.2.3 Potassium uptake in grain and straw of rice

The data regarding to the uptake of potassium by grain and straw (Sahyadri-4) of rice crop as influenced by various treatments is given in Table 28 (Fig 27 and 28) for first and second year of experiment and discussed below.

4.4.2.3.1 Potassium uptake in grain:

The data reveals that the uptake of potassium by grain of rice was observed to be vary from 28.29 to 49.59 mg kg⁻¹ and 27.81 to 44.46 mg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively.

Table 28: Effect of different treatments on uptake of potassium by grain and straw of rice crop at harvest stage

Treatment	2012 mg kg ⁻¹			2013 mg kg ⁻¹		
	Grain K uptake	Straw K uptake	Total K uptake	Grain K uptake	Straw K uptake	Total K uptake
T ₁	37.0	278.64	315.7	36.98	262.9	299.9
T ₂	40.95	328.04	368.9	42.24	293.5	335.7
T ₃	43.07	337.23	380.3	43.59	314.9	358.5
T ₄	45.62	326.30	371.9	41.28	357.8	399.1
T ₅	47.70	380.26	427.9	42.84	400.2	443.0
T ₆	49.59	388.12	437.7	44.46	404.0	448.4
T ₇	28.29	215.98	244.2	27.81	216.3	244.1
T ₈	29.97	227.93	257.9	29.84	227.6	257.5
T ₉	30.83	228.80	259.6	31.21	231.5	262.7
SEm _±	2.84	11.49	11.97	2.25	9.90	10.1
CD@ 1%	8.18	33.09	34.48	6.48	28.52	29.2

In Lateritic soil, the uptake of potassium by grain of rice, varied from 37.0 to 43.07 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 36.98 to 43.59 mg kg⁻¹. In Medium black soil, uptake of potassium by grain of rice varied from 45.62 to 49.59 mg kg⁻¹ and 41.28 to 44.46 mg kg⁻¹ during first year of experiment and in second year of experiment. In Coastal saline soil, uptake of potassium by grain of rice varied from 28.29 to 30.83 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 27.81 to 31.21 mg kg⁻¹. The uptake of potassium by grain of rice was found to be significantly superior (49.59 mg kg⁻¹ in 2012 and 44.46 mg kg⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment in the both year of experiment but in the first year it was found at par with T₄, T₃, T₆ and T₅ treatment while in the second year it was found at par with T₄, T₅, T₃ and T₂ treatments.

Among the various soil types, uptake of potassium by grain was found to be maximum in Medium black soil (41.28 to 49.59 mg kg⁻¹) followed by Lateritic soil (41.28 to 45.59 mg kg⁻¹) and was minimum in Coastal saline soil (27.81 to 31.21 mg kg⁻¹). The highest uptake of potassium by grain was found in Medium black soil treatment in the present study. Similar results were reported by Patil (2001).

Application of pesticides (Carbofuron and Phorate) increased uptake of potassium by grain of rice as compared to pesticide untreated. This may be due to higher availability of potassium content in pesticide treated soil than pesticide untreated soil. Bagal (2009).

Among the pesticides, the treatments receiving Phorate recorded the highest uptake of potassium by grain of rice in which were higher over Carbofuron and RDF treated treatment irrespective of soil type. This might be due to the Phorate was more effectiveness than compared to Carbofuron in contributing to the higher value of availability of potassium content irrespective of soil type.

4.4.2.3.2 Potassium uptake by straw:

The data regarding the uptake of potassium by straw of (Sahyadri-4) rice crop as influenced by various treatments is given in Table 28 (Fig) for first and second year of experiment and discussed below.

The data reveals that the uptake of potassium by straw of rice was observed to be varied from 215.98 to 388.12 mg kg⁻¹ and 216.3 to 404.0 mg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the uptake of potassium by straw of rice, varied from 278.6 to 337.2 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 262.9 to 314.9 mg kg⁻¹. In Medium black soil, uptake of potassium by straw of rice varied from 326.30 to 388.12 mg kg⁻¹ and 357.8 to 404.0 mg kg⁻¹ during first and in second year of experiment respectively. In Coastal saline soil uptake of potassium by straw of rice varied from 215.98 to 228.80 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 216.3 to 231.5 mg kg⁻¹. The uptake of potassium by straw of rice was found to be significantly superior (388.12 mg kg⁻¹ in 2012 and 404.0 mg kg⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment in the both year of experiment which was at par with T₅ treatment.

Among the various soil types, uptake of potassium by straw was found to be maximum in Medium black (326.30 to 404.0 mg kg⁻¹) followed by Lateritic soil (262.9 to 337.23 mg kg⁻¹) and was minimum in Coastal saline soil (215.98 to 231.5 mg kg⁻¹). The higher potassium content in straw was found in Medium black soil treatment over Lateritic soil type in the present study. Similar results were reported by Patil (2001).

Application of pesticides (Carbofuron and Phorate) increased uptake of potassium by straw of rice as compared to pesticide untreated soil i.e 100 per cent RDF alone irrespective of soil type. This may be due to higher availability of potassium content in pesticide treated soil than pesticide untreated soil. Bagal (2009).

Among the pesticides, the treatments receiving Phorate recorded the highest uptake of potassium by straw of rice. This might be due to the Phorate which was more effective as compared to Carbofuron in contributing to the higher availability of potassium irrespective of soil type.

4.4.2.3.3 Uptake of potassium by total biomass:

The data regarding to the uptake of potassium by total biomass of (Sahyadri-4) rice crop as influenced by various treatments is given in Table 28 (Fig). for first and second year of experiment and discussed below.

The data revealed that the uptake of potassium by total biomass of rice was observed to be varied from 244.2 to 437.7 mg kg⁻¹ and 244.1 to 448.4 mg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the uptake of potassium by total biomass of rice, varied from 315.7 to 380.3 mg kg⁻¹ during first year of experiment and in second year of experiment, its content

varied from 299.9 to 358.5 mg kg⁻¹. In Medium black soil, uptake of potassium by total biomass of rice varied from 371.9 to 437.7 mg kg⁻¹ and 399.1 to 448.4 mg kg⁻¹ during first year of experiment and in second year of experiment respectively. In Coastal saline soil, uptake of potassium by total biomass of rice varied from 244.2 to 259.6 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 244.1 to 262.7 mg kg⁻¹. The uptake of potassium by total biomass of rice was found to be significantly superior (437.7 mg kg⁻¹ in 2012 and 404.0 mg kg⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment in the both year of experiments which was found at par with T₅ treatment .

Among the various soil types, uptake of potassium by total biomass of rice was found be maximum in Medium black (371.9 to 448.4 mg kg⁻¹) followed by Lateritic soil (299.9 to 380.3 mg kg⁻¹) and was minimum in Coastal saline soil (244.1 to 262.7 mg kg⁻¹). The higher uptake of potassium by total biomass of rice in Medium black soil treatment was reported by Patil (2001).

4.5 Pesticides content in grain and straw of rice crop in different soil types and pesticides.

The pesticides content in grain and straw of rice recorded during the two years study indicated there were significant differences with the various treatments. The data regarding to the pesticides content in grain and straw of rice (Sahyadri-4) as influenced by various treatments is given in Table 29 (Fig 29 and 30) for first and second year of experiment.

4.5.1 Pesticides content in grain

The data reveals that the pesticides content in grain of rice is observed to vary from 14.80 to 29.13 µg kg⁻¹ and 15.76 to 25.36 µg kg⁻¹ among the different treatments of rice in first and second year of experiment respectively. The pesticides content in grain of rice was found to be significantly superior (29.13 and 25.36 µg kg⁻¹ in first and second year respectively) in (Medium black soil + RDF + Carbofuran) treatment in the both years of experiment.

TABLE. 29 Effect of different treatments on pesticides content in grain and straw of rice

Pesticides content	µg kg ⁻¹ (2012)							
	Lateritic		Medium black		Coastal saline		SEm _±	C.D.
	PI	PII	PI	PII	PI	PII		
Grain	20.56	17.40	29.13	23.56	16.76	14.80	0.66	2.05
Straw	12.53	10.50	16.53	13.76	9.73	7.86	0.35	1.10
	µg kg ⁻¹ (2013)							

Grain	21.43	19.60	25.36	22.4	19.46	15.76	0.68	2.09
Straw	13.63	11.56	17.73	14.93	10.50	6.86	0.56	1.73

PI: Carbofuron, **PII:** Phorate

In Lateritic soil, the pesticides content in grain of rice, varied from 17.40 to 20.56 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of experiment, its content varied from 19.60 to 21.43 $\mu\text{g kg}^{-1}$. In Medium black soil, the pesticides content in grain of rice varied from 16.76 to 23.56 $\mu\text{g kg}^{-1}$ and 22.4 to 25.36 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment respectively. In Coastal saline soil, the pesticides content in grain of rice varied from 14.80 to 16.76 $\mu\text{g kg}^{-1}$, during first year of experiment while in second year of experiment, its content varied from 15.76 to 19.46 $\mu\text{g kg}^{-1}$. Valliappan (1987) reported the similar results.

Among the various soil types, the studies of pesticides content in grain was found to be maximum in Medium black soil followed by Lateritic soil and was minimum in Coastal saline soil. The residue content of pesticides in smectitic dominated soil was found highest as compared to Kaolinitic dominated soils. (Yaron 1978). He further concluded that residues content of pesticides increased with increasing swelling capacity of clay because of swelling type (Smectite) clay. Pesticides residues get absorbed in Smectite type of clay structure in higher amount whereas the pesticides residues get adsorbed on the Kaolinite type. The pesticides content in grain of rice was found to be lowest in Coastal saline soil might be due to the saline nature of Coastal saline soil. Soil salinity usually brings about low pesticides availability to crop due to higher and faster degradation rate of applied pesticides. Battala *et al.* (2012) showed that applied pesticide degraded faster in saline condition as compared to non saline condition leads to low residues content in soil. Among the pesticides, the treatments receiving Carbofuron (PI) recorded the highest pesticides content in grain of rice which were higher over Phorate (PII) treated treatment irrespective of soil type.

The grain content in pesticides in the present study is found below maximum residue limit fixed by WHO and USEPA. Kumar *et al.*, (2006) the residue of Carbofuron and phorate was detected below maximum residue limit of 0.1 mg kg^{-1} in grain after harvest.

4.5.2 Pesticides content in straw:

The data regarding to the pesticides content in straw of (Sahyadri-4) rice crop as influenced by various treatments are given in Table 29 (Fig 29 and 30). For first and second year of experiment. The effect of application of pesticides in different types of soil was observed to be positive and statistically significant.

The data reveals that the pesticides content in straw of rice is observed to vary from 7.86 to 16.53 $\mu\text{g kg}^{-1}$ and 6.86 to 17.73 $\mu\text{g kg}^{-1}$ among the different treatments of rice in first and second year of experiment respectively.

In Lateritic soil, the pesticides content in straw of rice, varied from 10.50 to 12.53 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of experiment, its content varied from 11.56 to 13.63 $\mu\text{g kg}^{-1}$. In Medium black soil, the pesticides content in straw of rice varied from 13.76 to 16.53 $\mu\text{g kg}^{-1}$ and 14.93 to 17.73 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment respectively. In Coastal saline soil, the pesticides content in straw of rice varied from 7.86 to 9.73 $\mu\text{g kg}^{-1}$, during first year of experiment while in second year of experiment, its content varied from 6.86 to 10.50 $\mu\text{g kg}^{-1}$. Valliappan (1987) reported the similar results. The pesticides content in straw of rice was found to be significantly superior (16.53 to 9.37 $\mu\text{g kg}^{-1}$ and 10.50 to 17.73 $\mu\text{g kg}^{-1}$ in first and second year of experiment respectively) in (Medium black soil + RDF + Carbofuron) treatment in the both years of experiment.

Among the various soil types, the pesticides content in straw was found to be maximum in Medium black followed by Lateritic soil and was observed to be minimum in Coastal saline soil. This may be due to higher availability of pesticide to crop in Medium black soil than other two soil Types. Yaron (1978). He further concluded that residues content of pesticides increased with increasing swelling capacity of clay because of swelling type (Smectite) clay. Pesticides residues get absorbed in Smectite type of clay structure in higher amount whereas the pesticides residues get adsorbed on the Kaolinite type.

The pesticides content in straw of rice in the present study is found below maximum residue limit fixed by WHO and USEPA. Seiber *et al.*, (1978) also showed that the residues of pesticides in rice plants did not exceed the 0.2 mg kg^{-1} .

4.6 Effect of treatments on changes in available primary nutrients and pesticides residues in soil at different growth stages.

The data pertaining to the changes in available N , P_2O_5 , K_2O and pesticides residues in soil at different growth stages viz. 30, 60, 90 DAT (day after transplanting) and at harvest of rice as influenced by different treatments is presented and discussed below.

4.6.1. Effect of treatments on available Nitrogen (kg ha^{-1})

The periodic observations of available N in soil showed that the content varied from 308.6 to 363.0 kg ha^{-1} at 30 DAT, 340.9 to 383.4 kg ha^{-1} at 60 DAT, 296.9 to 341.9 kg ha^{-1} at 90

DAT and 284.8 to 342.4 kg ha⁻¹ at harvest stage of rice during first year of experiment. In the second year of experiment, its content varied from 310.7 to 357.1 kg ha⁻¹ at 30 DAT, 334.2 to 376.2 kg ha⁻¹ at 60 DAT, 302.0 to 330.1 kg ha⁻¹ at 90 DAT and 279.4 to 348.3 at harvest stage of rice. Table 30 (Fig31 and 32).

Table 30: Effect of different treatment on available nitrogen at different growth stages of rice

Treatment	kg ha ⁻¹ (2012)				kg ha ⁻¹ (2013)			
	30 DAT	60 DAT	90 DAT	AH	30 DAT	60 DAT	90DAT	AH
T ₁	333.4	354.4	296.9	301.1	326.8	342.1	302.0	299.6
T ₂	353.6	376.8	306.5	307.2	344.9	362.1	309.1	305.1
T ₃	358.5	383.4	310.1	309.6	351.8	371.2	313	307.7
T ₄	308.6	340.9	298.5	284.8	310.7	334.2	306.2	279.4
T ₅	336.1	370.1	316.7	292.8	332.0	363.3	324.1	288.1
T ₆	345.6	380.2	319.9	295.4	341.0	376.2	330.1	292.1
T ₇	344.1	356.1	334.7	338.1	338.2	350.1	318.1	342.2
T ₈	359.4	372.2	340.2	341.5	352.0	361.0	324.0	346.0
T ₉	363.0	375.1	341.9	342.4	357.1	366.1	327.2	348.3
SEm±	4.75	2.79	2.75	2.23	4.21	2.35	2.43	2.32
CD@ 1%	13.6	11.3	11.1	9.11	12.12	9.56	9.90	9.47

In Lateritic soil, available N content at 30DAT varied from 333.4 to 358.5 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 326.8 to 351.8 kg ha⁻¹. In Medium black soil, available N content varied from 308.6 to 345.6 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 310.7 to 341 kg ha⁻¹. In Coastal saline soil, available N content at 30DAT varied from 344.1 to 363.0 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 338.2 to 357.1 kg ha⁻¹. The available nitrogen at 30DAT was found to be significantly superior in T₉ (Coastal saline soil + RDF+ Phorate) treatment (363.0 kg ha⁻¹ in 2012 and 352.0 kg ha⁻¹ in 2013) which was at par with T₂, T₃ and T₈ in both the years of experiment.

At 60DAT, the available nitrogen content in Lateritic soil, varied from 354.4 to 383.4 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from

372.2 to 351.8 kg ha⁻¹. In Medium black soil, available N content varied from 340.9 to 380.2 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 334.2 to 376.2 kg ha⁻¹. In Coastal saline soil, available N content varied from 356.1 to 375.1 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 350.1 to 366.1 kg ha⁻¹. The significantly superior available nitrogen at 60DAT (383.44 kg ha⁻¹) was found in T₃ (Lateritic soil + RDF + Phorate) treatment which was at par with T₂, T₅, T₆, T₈ and T₉ treatment during 2012. However during 2013, the significantly higher (376.2 kg ha⁻¹) available nitrogen at 60DAT was found in T₆ (Medium black soil + RDF + Phorate) treatment which was at par with T₉ treatment.

At 90DAT, the available nitrogen content in Lateritic soil, varied from 296.9 to 310.1 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 302.0 to 313 kg ha⁻¹. In Medium black soil, available N content at 90DAT varied from 298.5 to 319.9 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 306.2 to 330.1 kg ha⁻¹. In Coastal saline soil, available N content at 90DAT varied from 334.7 to 341.9 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 318.1 to 327.2 kg ha⁻¹. The available nitrogen at 90DAT was found significantly superior (341.9 kg ha⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) treatment which was at par with T₈ treatment during the first year. However during the second year, available nitrogen at 90DAT was found significantly superior (327.2 kg ha⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) treatment which was at par with T₅, T₆, and T₈ treatment.

At harvest stage of rice, the available nitrogen content in Lateritic soil, varied from 301.19 to 309.6 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 299.6 to 307.7 kg ha⁻¹. In medium black soil, available N content varied from 248.8 to 295.4 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 279.4 to 292.1 kg ha⁻¹. In Coastal saline soil, available N content at harvest stage varied from 338.1 to 342.4 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 342.2 to 348.3 kg ha⁻¹. The available nitrogen at harvest stage was found significantly superior (342.4 in 2012 and 348.3 kg ha⁻¹ in 2013) in T₉ (Coastal saline soil + RDF + Phorate) treatment which was at par with T₈ and T₇ treatment during the both year.

Maximum available N content was recorded at 60DAT stage in all the treatments and in both the years. The reason for maximum N content at 60 DAT irrespective of the soil type in all the treatments is attributed to the decomposition of organic matter and split application of N. On the other hand maximum available N content in pesticides treated soil at 60 DAT was

observed than pesticides untreated treatment. Das *et al.*, (2003) reported that, available nitrogen attains a highest peak at 60 DAT due to application of insecticides (Phorate, Carbofuron at their recommended dose at the time of transplanting of rice) over the pesticides untreated treatments. The available N content of soil in all treatments declined at 90 DAT. This may be due to the fact that soils are percolative in nature and leaching losses of nitrogen and denitrification under submerged conditions. The nitrogen uptake by the plants can be another reason for decline. Similar results were quoted by Das and Mukherjee (1994). Das and Mukherjee (1998b) also showed that the available N was recorded highest at 60DAT stage and decreased 90DAT in pesticides as well as in pesticide untreated observations i.e. RDF alone treatment.

It was observed that there was an increase in available N nitrogen content in the pesticides (Carbofuron and Phorate) treated soils along with 100 percent RDF as compared to pesticide untreated soil i.e 100 percent RDF alone irrespective of soil type. Das *et al.*, (2003) reported that application if insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils. The phorate was more effective than compared to carbofuron in contributing to the higher value of available N content. They also showed that the increase in nitrogen availability was more in case of Phorate as compared to Carbofuron may be due to stimulation was more pronounced with Phorate as compared to Carbofuran resulting in increased population size and activity of microorganisms which in turn influences the transformation of plant nutrient element in soil and increasing its availability of nitrogen.

4.6.2 Effect of different treatment on available phosphorous at different growth stages of rice (kg ha⁻¹)

The periodic observations of available P₂O₅ content in soil showed that the content varied from 12.9 to 30.5 kg ha⁻¹ at 30DAT, 15.60 to 33.10 kg ha⁻¹ at 60DAT, 13.4 to 31.9 kg ha⁻¹ and 11.8 to 28.2 kg ha⁻¹ at harvest stage of rice during first year of experiment. In the second year of experiment, the content varied from 13.1 to 29.4 kg ha⁻¹ at 30DAT, 16.0 to 31.6 kg ha⁻¹ at 60DAT, 13.8 to 29.8 kg ha⁻¹ at 90DAT and 12.0 to 26.76 at harvest stage of rice Table 31 (Fig 33 and 34).

It can be observed from the data that the available P₂O₅ content under various treatments was significantly influenced.

Table 31: Effect of different treatment on available phosphorous at different growth stages of rice.

Treatment	Ava. P ₂ O ₅ kg ha ⁻¹ (2012)				Ava. P ₂ O ₅ kg ha ⁻¹ (2013)			
	30 DAT	60 DAT	90 DAT	AH	30 DAT	60 DAT	90 DAT	AH
T ₁	12.9	15.60	13.4	11.8	13.1	16.0	13.8	12.0
T ₂	14.7	17.80	14.6	12.5	14.8	18.9	15.0	12.8
T ₃	15.53	18.50	15.0	12.8	15.4	19.7	15.4	13.2
T ₄	22.93	26.50	24.6	23.4	20.2	24.1	23.2	21.8
T ₅	25.2	29.90	26.5	24.6	23.3	27.1	24.1	23
T ₆	25.8	30.70	27.0	25.5	24.1	28.7	24.7	23.9
T ₇	28.9	32.00	30.8	27.7	27.5	30.5	29.2	26.2
T ₈	30.1	32.90	31.6	28	28.9	31.2	29.6	26.5
T ₉	30.5	33.10	31.9	28.2	29.4	31.6	29.8	26.76
SEm±	0.62	0.61	0.49	0.41	0.50	0.53	0.54	0.42
CD@ 1%	2.55	2.48	2.02	1.70	2.06	2.15	2.19	1.71

In Lateritic soil, available P₂O₅ content at 30DAT varied from 12.9 to 15.53 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 13.1 to 15.4 kg ha⁻¹. In Medium black soil, available P₂O₅ content varied from 22.93 to 25.8 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 20.2 to 24.1 kg ha⁻¹. In Coastal saline soil, available P₂O₅ content varied from 28.91 to 30.5 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 27.5 to 29.4 kg ha⁻¹. The available P₂O₅ at 30DAT was found to be significantly superior (30.5 kg ha⁻¹) in T₉ (Coastal saline soil +RDF + Phorate) treatment which was at par with T₈ in first year of experiment whereas its content at 30DAT was found to be significantly superior (29.4 kg ha⁻¹) in T₉ (Coastal saline soil +RDF + Phorate) treatment which was at par with T₈ and T₇ in second year of experiment.

At 60DAT, the available P₂O₅ content in Lateritic soil, varied from 15.60 to 18.50 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 16.0 to 19.7 kg ha⁻¹. In Medium black soil, available P₂O₅ content varied from 26.5 to 30.7 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 24.1 to 28.7 kg ha⁻¹. In Coastal saline soil, available P₂O₅ content at 60DAT varied from 32.0 to 33.1 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 30.5 to 31.6 kg ha⁻¹. The available P₂O₅ At 60DAT was found to be significantly superior

(33.10 kg ha⁻¹) in T₉ (Coastal saline soil +RDF + Phorate) treatment which was at par with T₈ and T₇ treatment during the first year. However during the second year, the available P₂O₅ at 60 DAT was also found to be significantly superior in (31.6 kg ha⁻¹) T₉ (Coastal saline soil +RDF + Phorate) treatment which was at par with T₈ treatment.

At 90DAT, the available P₂O₅ content in Lateritic soil, varied from 13.40 to 15.0 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 13.8 to 15.4 kg ha⁻¹. In Medium black soil, available P₂O₅ content at 90DAT increases from 24.6 to 27.0 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 23.2 to 24.7 kg ha⁻¹. In Coastal saline soil, P₂O₅ content varied from 30.8 to 31.9 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 29.2 to 29.8 kg ha⁻¹. The available P₂O₅ at 90DAT was found to be significantly superior (31.9 kg ha⁻¹ in 2012 and 29.8 kg ha⁻¹ in 2013) in T₉ (Coastal saline soil +RDF + Phorate) treatment which was at par with T₈ and T₇ treatment during both the year.

At harvest stage of rice, the available P₂O₅ content in Lateritic soil, varied from 11.8 to 12.8 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 12.0 to 13.2 kg ha⁻¹. In Medium black soil, available P₂O₅ content varied from 23.4 to 27.0 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 21.8 to 23.9 kg ha⁻¹. In Coastal saline soil, available P₂O₅ content varied from 27.7 to 28.2 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 26.2 to 26.7 kg ha⁻¹. The available P₂O₅ at harvest stage was found to be significantly superior (28.2 kg ha⁻¹) in T₉ (Coastal saline soil +RDF + Phorate) treatment which was at par with T₈, T₇ and T₆ treatment during the first year. Similarly during the second year, the available P₂O₅ at harvest stage was found to be significantly superior (26.5 kg ha⁻¹) in T₉ (Coastal saline soil +RDF + Phorate) treatment which was at par with T₈ and T₇ treatments.

Maximum available P₂O₅ content was recorded at 60 DAT stage in all the treatments and in both the years. The reason for maximum available P₂O₅ content at 60DAT irrespective of soil type in all the treatment may be partly due to the decomposition of organic matter and submerged conditions.

It was observed that there was an increase in available P₂O₅ nitrogen content in the pesticides (Carbofuron and Phorate) treated treatments along with 100 per cent RDF as compared to pesticide untreated soil i.e 100 per cent RDF alone irrespective of soil type. Madhuri and Rangaswamy (2000), Das and Mukherjee (1994) and Das and Mukherjee (2000b) reported the similar results. Das and Mukherjee, (1994) also reported the increase in P

availability and higher mineralization of P with the incorporation of insecticides Phorate and Carbofuran suggesting that insecticides significantly increased the phosphate solubilizing/mineralizing microorganisms and availability of P_2O_5 in soil.

The Phorate was more effective than compared to Carbofuron in contributing to the higher value of available P_2O_5 content. Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in P_2O_5 availability was more in case of Phorate as compared to Carbofuron. The results in the present investigation are in agreement with Parvaze *et al.*, (2005) showed that increase in available P_2O_5 in soil with application of Phorate brought about a significant stimulation of growth and activities of PSB which in turn transformed the unavailable form of P into more available form as compared to Carbofuron as well as pesticides untreated treatments. Das and Mukherjee (1998b) also showed that the increased in P_2O_5 availability was more in case of Phorate as compared to Carbofuron. Das *et al.*, (2003) reported that application if insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB in the rice rhizosphere soils, and they also observed stimulation was more pronounced with Phorate as compared to Carbofuran resulting in increased population sizes and activities of microorganisms which in turn influences the transformation of plant nutrient in soil and increasing the availability of P_2O_5 .

4.6.3 Effect of different treatment on available potassium at different growth stages of rice. ($kg\ ha^{-1}$)

The periodic observations of available K_2O content in soil showed that the content varied from 297.3 to 1087.7 $kg\ ha^{-1}$ at 30DAT, 286.1 to 1099.1 $kg\ ha^{-1}$ at 60DAT, 271.1 to 1138.2 $kg\ ha^{-1}$ at 90DAT and 269 to 1087.6 $kg\ ha^{-1}$ at harvest stage of rice during first year of experiment. In the second year of experiment, its content varied from 295.1 to 1072.3 $kg\ ha^{-1}$ at 30DAT, 286.1 to 1102.9 $kg\ ha^{-1}$ at 60DAT, 268.2 to 1126.0 $kg\ ha^{-1}$ at 90DAT and 261.0 to 1078.6 at harvest stage of rice. Table 32 (Fig 35 and 36). It can be observed from the data that the available K_2O under various treatments was significantly influenced.

Table 32 Effect of different treatment on available potassium at different growth stages of rice.

Treatment	Ava. $K_2O\ kg\ ha^{-1}$ (2012)				Ava. $K_2O\ kg\ ha^{-1}$ (2013)			
	30 DAT	60 DAT	90 DAT	AH	30 DAT	60 DAT	90 DAT	AH
T ₁	297.3	286.1	271.1	269	295.1	280.2	268.2	261.0

T ₂	309.2	295	275.2	272.3	305.2	288.1	273.0	264.1
T ₃	312.1	297	276.2	272.6	310.6	291.2	275.2	265.4
T ₄	325	317.2	307.2	299.1	306.0	293.0	283.1	274.1
T ₅	343.2	329.1	316.0	299.5	322.1	305.2	293.1	281.1
T ₆	348.3	332.3	318.2	300.5	326.1	309.2	296.1	283.1
T ₇	1084.2	1096.1	1136	1086.0	1067.1	1090.1	1123.1	1077.1
T ₈	1086.5	1098.0	1137.6	1087.2	1070.5	1100.3	1125.1	1078.0
T ₉	1087.7	1099.1	1138.2	1087.6	1072.3	1102.9	1126.0	1078.8
SEm _±	2.5	2.9	2.73	3.50	2.56	2.72	2.92	2.93
CD@ 1%	10.2	11.9	11.13	14.2	10.4	11.1	11.88	11.96

In Lateritic soil, available K₂O content at 30 DAT varied from 297.3 to 312.1 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 295.1 to 310.6 kg ha⁻¹. In Medium black soil, available K₂O content varied from 325 to 348.3 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 306.0 to 326.1 kg ha⁻¹. In Coastal saline soil, available K₂O content varied from 1084.2 to 1087.7 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 1067.1 to 1072.2 kg ha⁻¹. The available K₂O at 30 DAT was found to be significantly superior in T₉ (Coastal saline soil +RDF + Phorate) treatment (1087.7 kg ha⁻¹ in 2012 and 1072.3 kg ha⁻¹ in 2013) which was at par with T₇ and T₈ in both the year of experiment.

At 60 DAT, the available K₂O content in Lateritic soil, varied from 286.10 to 297 kg ha⁻¹ during first year of experiment and in second year of experiment, its content increased from 280.21 to 291.20 kg ha⁻¹. In Medium black soil, available K₂O content varied from 317.20 to 332.30 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 293.01 to 309.23 kg ha⁻¹. In Coastal saline soil, available K₂O content varied from 1096.12 to 1099.10 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 1090.1 to 1102.9 kg ha⁻¹. The available K₂O at 60 DAT was found to be significantly superior in T₉ (Coastal saline soil +RDF + Phorate) treatment (1099.1 kg ha⁻¹ in 2011 and 1102.9 kg ha⁻¹ in 2013) which was at par with T₇ and T₈ in both the year of experiments.

At 90DAT, the available K₂O content in Lateritic soil, varied from 271.1 to 276.2 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from

268.2 to 275.2 kg ha⁻¹. In Medium black soil, available K₂O content varied from 307.2 to 318.2 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 283.1 - 296.1 kg ha⁻¹. In Coastal saline soil, available K₂O content varied from 1136.0 to 1138.2 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 1123.1 to 1126.0 kg ha⁻¹. The available K₂O at 90 DAT was found to be significantly superior in T₉ (Coastal saline soil +RDF + Phorate) treatment (1138.2 kg ha⁻¹ in 2012 and 1126.09 kg ha⁻¹ in 2013) which was at par with T₇ and T₈ in both the year of experiments.

At harvest stage of rice, the available K₂O content in Lateritic soil, varied from 269.0 to 272.6 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 261.0 to 265.4 kg ha⁻¹. In Medium black soil, available K₂O content varied from 299.1 to 300.52 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 274.1 to 283.1 kg ha⁻¹. In Coastal saline soil, available K₂O content varied from 1086.0 to 1087.6 kg ha⁻¹ during first year of experiment and in second year of experiment, its content varied from 1077.1 to 1077.8 kg ha⁻¹. The available K₂O at harvest stage was found to be significantly superior in T₉ (Coastal saline soil +RDF + Phorate) treatment ((1087.6 kg ha⁻¹ in 2012 and 1078.8 kg ha⁻¹ in 2013) which was at par with T₇ and T₈ in both the year of experiments.

It was observed that application of pesticides (Carbofuron and Phorate) increase the available K₂O content as compared to pesticide untreated soil irrespective of soil type. Similar results were quoted by Bagal (2009).

Maximum available K₂O content was recorded at 30DAT stage as compared to further sampling in Lateritic soil and Medium black soil in both the years of experiments. The reason for maximum available K₂O in soil at 30DAT may be due to the basal application full dose of potassium fertilizers. Thereafter the available K₂O content in soil showed declined trend from 30DAT to at harvest stage in Lateritic soil and Medium black soil may be attributed to the fact that soils probable K₂O losses and due to leaching as well as K₂O uptake by the plants under submerged conditions.

However in case of Coastal saline soil the available K₂O content in soil increased from 30DAT to 90DAT and found highest at 90DAT stage may be due higher native potassium status of saline soil. The available K₂O content of soil decreased to a certain extent from 90DAT to at harvest stage in Coastal saline soil.

4.6.4 Effect of treatments on residues of pesticides in soil (µg kg⁻¹)

Table 33: Effect of different treatment on pesticides residues in soil at different growth stages of rice. (2012)

DAT	Residues in soil $\mu\text{g kg}^{-1}$ (2012)							
	Lateritic		Medium black		Coastal saline		SEm $\pm$	C.D. @ 1%
	PI	PII	PI	PII	PI	PII		
30	1104.7	634	1326.4	764.6	920.3	499.5	25.09	54.6
60	440.1	166.3	581.8	260.7	380.3	122.4	15.5	33.9
90	147.7	49.1	258.8	112.6	103.2	40.6	9.73	21.2
AH	58	35.1	88.3	53.4	44.9	23.9	5.36	11.6

Table 34: Effect of different treatment on pesticides residues in soil at different growth stages of rice. (2013)

DAT	Residues in soil $\mu\text{g kg}^{-1}$ (2013)							
	Lateritic		Medium black		Coastal saline		SEm $\pm$	C.D. @1%
	PI	PII	PI	PII	PI	PII		
30	1184.6	676.3	1472.4	859.5	891.7	488.7	15.8	34.4
60	380.0	122.9	503.6	204.7	284.6	71.3	8.85	19.2
90	183.6	68.3	302.1	139.7	139.7	58.4	5.60	12.6
AH	45.3	31.5	67.6	38.3	37.1	29.3	5.59	12.1

The data pertaining to the changes in pesticides residues in soil at different growth stages viz. 30, 60, 90 DAT (day after transplanting) and at harvest of rice as influenced by different treatments are presented in Table 33 and 34 (Fig 37 and 38).

The periodic observations of pesticides residues in soil showed that its content varied from 449.5 to 1326.4 $\mu\text{g kg}^{-1}$, 122.4 to 581.8 $\mu\text{g kg}^{-1}$, 40.6 to 258.8 $\mu\text{g kg}^{-1}$ and 23.9 to 88.3 $\mu\text{g kg}^{-1}$ at 30DAT, 60DAT, and 90DAT and at harvest stage of rice during first year of experiment (Table 33) In the second year of experiment, its content varied from 488.7 to 1472.4 $\mu\text{g kg}^{-1}$, 71.3 to 503.6 $\mu\text{g kg}^{-1}$, 58.4 to 302.1 $\mu\text{g kg}^{-1}$ and 29.3 to 67.6 $\mu\text{g kg}^{-1}$ at 30 DAT, 60DAT, and 90DAT and at harvest stage of rice. (Table 34). It can be observed from the data that under various treatments pesticides residue was significantly influenced.

In Lateritic soil, pesticide residue in soil content at 30 DAT varied from 634.0 to 1104.7 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment, its content varied from 676.3 to 1184.6 $\mu\text{g kg}^{-1}$. In Medium black soil, pesticide residue in soil at 30 DAT varied from 764.6 to 1326.4 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment, its content varied from 859.5 to 1472.4 $\mu\text{g kg}^{-1}$. In Coastal saline soil, pesticide residue content in soil at 30 DAT varied from 499.5 to 920.3 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment, its content varied from 488.7 to 891.7 $\mu\text{g kg}^{-1}$. Pesticides residues content at 30 DAT was recorded significantly highest (1326.4 and 1472.4 $\mu\text{g kg}^{-1}$ in the first year and second year of experiment respectively) in Medium black soil with the application of (Carbofuron +RDF).

At 60 DAT, pesticides residues in soil in Lateritic soil, varied from 166.2 to 440.1 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of experiment, its content varied from 122.9 to 380.0 $\mu\text{g kg}^{-1}$. In Medium black soil, pesticide residue in soil at 60 DAT varied from 260.7 to 581.8 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of experiment, its content varied from 204.7 to 503.6 $\mu\text{g kg}^{-1}$. In Coastal saline soil, pesticide residue content in soil at 90 DAT varied from 40.6 to 103.2 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of experiment, its content varied from 58.4 to 139.7 $\mu\text{g kg}^{-1}$. Pesticide residue content at 60 DAT was recorded significantly higher (258.8 and 302.1 $\mu\text{g kg}^{-1}$ in the both the years of experiment respectively) in Medium black soil with treatment receiving (Carbofuron+ RDF).

At 90DAT, the pesticide residue content in Lateritic soil, varied from 49.1 to 147.7 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of experiment, its content varied from 68.3 to 183.6 $\mu\text{g kg}^{-1}$. In Medium black soil, pesticide residue content at 90 days after transplanting varied from 112.6 to 258.8 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of experiment, its content varied from 139.7 to 302.1 $\mu\text{g kg}^{-1}$. In Coastal saline soil, pesticide residue content at 90 DAT varied from 23.9 to 44.9 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment, its content varied from 29.3 to 37.1 $\mu\text{g kg}^{-1}$. Pesticide residue content at 90 DAT was recorded significantly higher (258.8 and 302.1 $\mu\text{g kg}^{-1}$ both the years of experiment respectively) in Medium black soil with treatment (Carbofuron + RDF).

At harvest stage of rice, the pesticide residue content in Lateritic soil, varied from 35.1 to 58.0 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment, its content varied from 31.5 to 45.3 $\mu\text{g kg}^{-1}$. In Medium black soil, pesticide residue content at harvest varied from 53.4 to 88.3 $\mu\text{g kg}^{-1}$ during first year of experiment while in second year of

experiment, its content varied from 38.3 to 67.6 $\mu\text{g kg}^{-1}$. In Coastal saline soil, pesticide residue content at harvest stage varied from 23.9 $\mu\text{g kg}^{-1}$ to 44.9 $\mu\text{g kg}^{-1}$ during first year of experiment and in second year of experiment, its content varied from 37.1 to 29.3 $\mu\text{g kg}^{-1}$. Pesticide residue content at harvest was recorded significantly higher (88.3 and 67.6 $\mu\text{g kg}^{-1}$) during both years of experiment in Medium black soil with the treatment Carbofuron + 100 per cent RDF in the first and second year of experiment respectively.

It can be revealed from the observations that during all four stages (30, 60, 90 and at harvest stage) of sampling, the pesticide residue content was influenced due to the various treatments. The pesticide residue content was recorded highest at 30 DAT and afterwards it showed decreasing trend in subsequent observations and it was recorded minimum in the last observation (at harvest) in both the years of experiment irrespective of soil type. The decrease from 30 DAT to at harvest stage of rice and it may be because either due to the utilization of pesticides by crop or may be due processes like adsorption, degradation. The results in the present investigation are in agreement with Das and Mukherjee (1998b) and Das *et al.*, (2003).

Among all the soil types, the trend of pesticide residue content in soil was found viz. Medium black soil > Lateritic soil > Coastal saline soil. Among the various soil type under present study, the highest pesticides residues (PI and PII) content in soil was found significantly higher in Medium black soil in both the years over the other two soil types at all the stages (30, 60, 90 and at harvest stage). On the other hand the residues of both (PI and PII) pesticides in soil was found low in Coastal saline soil during both the years at all the stages (30, 60, 90 and at harvest stage). The higher pesticides residues content in smectitic rich soil was also recorded by Yaron (1978). He further concluded that residues content of pesticides increased with increasing swelling capacity of clay because of swelling type clay. Pesticides residues get absorbed and fixed in Smectite type of clay structure in higher amount whereas the pesticides residues get adsorbed on the Kaolinite type in lower amount. Keiger and Yaron (1975) also concluded that soils which contain Smectite clay retain Pesticides much more strongly than kaolinitic clays. The pesticides residues content in Lateritic soil (Kaolinitic rich) treatment was found low as compared to Medium black soil treatment in the present study. Similar results were quoted by Keiger and Yaron (1975). This may be due to higher leaching losses of applied pesticides (PI and PII) from Lateritic soil due to high infiltration rate, low CEC of soil as compared to other two soil types under study. Higher leaching losses of pesticides reduce the residues content in soil (Lateritic soil)

The residues of both (PI and PII) pesticides in soil was found low in Coastal saline soil treatment over the other two soil types under study might be because of saline nature of soil

which results in to faster degradation of both the pesticides. The faster degradation of pesticides in saline condition than compared to non saline condition was also reported by Bhattala *et al.*, (2013).

Among the two pesticides (PI and PII) treatment in the present study, the Carbofuron (PI) pesticide residue content was found higher as compared to Phorate (PII) content irrespective of soil at all the stages of rice growth. This may be due to faster degradation rate and low solubility (22 mg l^{-1}) of Phorate as compared to Carbofuron (350 mg l^{-1}). According to Bhuvaneswari *et al.*, (2011), Phorate residues degraded at faster rate as compared to Carbofuran in various treatments. Carbofuran moderately high affinity for adsorption to soil due to low degradation rate as compared to Phorate.

4.7 Effect of different treatments on form of primary nutrients (N,P and K) in soil at harvest stage of rice crop.

The data regarding the changes in the NPK fractions of soil at harvest of rice crop as influences by various treatments are given and discussed below for first and second year of experiment.

4.7.1 Effect of different treatments on form of nitrogen in soil at harvest stage of rice crop.

The data regarding the changes in the content of nitrogen fractions viz. Ammonical-N, nitrate-N and total exch. N (ammonical-N + nitrate-N) of soil at harvest of crop as influenced by various treatments is given in Table 35.

Table 35: Effect of different treatments on form of nitrogen in soil at harvest stage of rice crop

Treatment	N-fractions mg kg^{-1} (2012)			N-fractions mg kg^{-1} (2013)		
	Amm. - N	Nitrate- N	Total (Amm.+nitrate) -N	Amm.- N	Nitrate- N	Total (Amm.+Nitrate) -N
T ₁	34.5	19.6	54.1	32.4	17.4	49.8
T ₂	41.5	24.7	66.2	38.8	23.4	62.2
T ₃	43.6	27.0	70.8	40.5	25.5	66.0
T ₄	31.2	17.8	49.0	28.2	15.8	44.0
T ₅	39.4	24.2	63.6	34.4	20.9	55.3

T ₆	42.4	25.4	67.8	37.6	23.1	60.7
T ₇	39.1	25.2	64.3	40.4	26.7	67.1
T ₈	42.5	27.7	70.2	43.7	28.7	72.4
T ₉	43.7	28.6	72.3	45.1	29.5	74.6
S. Em _±	1.4	1.8		2.09	1.9	
CD@ 1%	4.1	5.1		6.01	5.5	

4.7.1.1 Ammonical-N fractions

The data presented in Table 35, reveals that the ammonical-N in soil were observed to be vary from 31.2 to 43.7 mg kg⁻¹ and 28.2 to 45.13 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively. It can be observed from the data that the ammonical-N under various treatments has been significantly influenced.

In Lateritic soil, ammonical-N content varied from 34.5 to 43.6 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 32.4 to 40.5 mgkg⁻¹. In Medium black soil, ammonical-N content varied from 31.2 to 42.4 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 28.2 to 37.6 mg kg⁻¹. In Coastal saline soil, ammonical-N content varied from 39.1 to 43.76 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 40.4 to 45.13 mg kg⁻¹. The ammonical-N was found to be significantly higher (43.76 mg kg⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) treatment in the first year of experiment which was at par with T₈, T₆, T₃ and T₂ in and in the second year of experiment its content was also found to be significantly higher in (45.13 mg kg⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) treatment in the second year of experiment which was at par with T₈, T₂, T₆ and T₃ treatments.

Application of pesticides (Carbofuron and Phorate) increased the ammonical-N content in the soil at harvest of rice as compared to pesticide untreated soil i.e 100 per cent RDF alone irrespective of soil type. Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported the similar results. They all found that mineralization of N increased due to the application of insecticides in soil under rice crop. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils whereas Singh and Prasad (1991), reported an increase in the amounts of ammonical-N in pesticides treated soil attributed due to the stimulation of the growth and activities of

ammonifying bacteria which were mainly responsible for mineralization of organic N and convert it into ammonical-N form.

Among the pesticides, the treatments receiving Phorate recorded the higher ammonical-N in soil after harvest of rice which were significantly superior over Carbofuron and RDF treated treatment irrespective of soil type. The Phorate were more effective than compared to Carbofuron in contributing to the higher value of ammonical-N content irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in ammonical-N availability was more in case of Phorate as compared to Carbofuron may be due to stimulation was more pronounced with Phorate as compared to Carbofuron resulting in increased population sizes and activities of ammonifying bacteria which in turn influences the transformations of plant nutrient elements in soil and increasing its availability of ammonical-N.

The data reveals that the application of nitrogenous fertilizers to rice significantly increased the ammonical-N content of soil in all the treatments over their respective initial values irrespective of soil type. Pednekar (1992) and Santhy *et al.*, (1998) reported that ammonical-N content increased in soil in all treatments over its initial status may be attributed due to the application of nitrogenous fertilizers.

Among the various soil types, ammonical-N found to be maximum Coastal saline soil followed by Lateritic soil and was minimum in Medium black soil. Ammonical-N content was recorded higher in Coastal saline soil might be due to exchange of fixed and native nitrogen with Na ions (which are a major part of soil cause of salinity) which results into releasing of native ammonical-N from the soil exchange complex as ammonical-N form. (Chattopadhyay and Mandal 1980). The low ammonical-N content of Medium black and Lateritic soil may be due to the fact that soils are percolative in nature and leaching losses of nitrogen and denitrification under submerged conditions.

4.7.1.2 Nitrate-N fractions

The data presented in Table 35, reveals that the nitrate-N in soil were observed to be varied from 17.8 to 28.6 mg kg⁻¹ and 15.8 to 29.5 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively. It can be observed from the data that the nitrate-N under various treatments was significantly influenced.

In Lateritic soil, nitrate-N content varied from 19.6 to 27.0 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 17.43 to 25.5 mg kg⁻¹. In Medium black soil, nitrate-N content varied from 17.8 to 25.4mg kg⁻¹ during first year and in

second year of experiment, its content varied from 15.8 to 23.1 mg kg⁻¹. In Coastal saline soil, nitrate-N content varied from 25.2 to 28.6 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 26.7 to 29.5 mg kg⁻¹. The nitrate-N was found to be significantly superior (28.6 mgkg⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) treatment in the first year of experiment which was at par with all treatments except T₄ and T₁ treatment. In the second year of experiment its content was found to be significantly superior (29.5 mgkg⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) treatment in the second year of experiment which was at par with T₈, T₇, T₂ and T₃ treatment.

Application of pesticides (Carbofuron and Phorate) increased the nitrate-N content in the soil at harvest of rice than pesticide untreated soil irrespective of soil type. Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported the similar results. They all found that mineralization of N increased due to the application of insecticides in soil under rice crop. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of bacteria, actinomycetes and fungi in the rice rhizosphere soils whereas Singh and Prasad (1991), reported an increase in the amounts of nitrate in pesticides treated soil attributed due to the stimulation of the growth and activities of nitrifying bacteria which were mainly responsible for mineralization of organic N and convert it into nitrate form.

Among the pesticides, the Phorate receiving treatments recorded the higher nitrate-N in soil after harvest of rice which was higher than Carbofuron irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) reported that Phorate was more effective than compared to Carbofuron in contributing to the higher value of nitrate-N content irrespective of soil type. Das *et al.*, (2003) also showed that the increased in nitrate-N availability was more in case of Phorate as compared to Carbofuron may be due to stimulation was more pronounced with Phorate as compared to Carbofuran resulting in increased population size and activity of nitrifying bacteria which in turn influences the transformations of plant nutrient elements in soil and increasing its availability of nitrate-N.

The overall data reveals that the nitrate-N content of soil significantly increased due to the application of fertilizers treatment irrespective of soil type over the respective initial values. Pednekar (1992) Santhy *et al.*, (1998) reported that nitrate-N content increased in soil in all treatments as compared to its initial status may be attributed due to the application of nitrogenous fertilizers.

Maximum nitrate-N content was recorded in Coastal saline soil. According to Bandyopadhyay *et al.*, (1983) the reason of higher accumulation of nitrate-N content in Coastal saline soil might be attributed to the antagonistic effect of chloride. The low value of nitrate-N content of Medium black soil and Lateritic soil treatments may be due to the fact that soils are percolative in nature and leaching losses of nitrogen and denitrification under submerged conditions

4.7.1.3 Total (ammonical+ nitrate) - N of soil

A total N fraction is the sum of fractions ammonical-N and nitrate-N. From the data presented in Table 35, it can be observed that the total-N in soil varied from 49.0 to 72.3 mg kg⁻¹ and 44.0 to 74.6 mg kg⁻¹ among the different treatments after harvest of rice in first and second year of experiment, respectively. The total N under various treatments was significantly influenced.

In Lateritic soil, total-N content varied from 54.1 mg kg⁻¹ to 70.8 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 49.8 to 66.0 mg kg⁻¹. In Medium black soil, total-N content varied from 49.0 to 67.8 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 44.0 to 60.7 mg kg⁻¹. In Coastal saline soil, total-N content varied from 64.3 to 72.36 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 67.1 to 74.6 mg kg⁻¹. The total-N was found to be highest (72.36 mg kg⁻¹ in 2012 and 74.63 mg kg⁻¹ 2013) in T₉ (Coastal saline soil + RDF + Phorate) treatment in the both years of experiments.

Application of pesticides (Carbofuron and Phorate) increased the in total-N content in the soil as compared to pesticide untreated soil irrespective of soil type. Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported the similar results. Among the pesticides, the Phorate receiving treatments recorded the higher total N in soil after harvest of rice which were significantly superior over Carbofuron irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also reported the similar results.

The overall data reveals that the total-N content of soil significantly increased due to the application of fertilizers irrespective of soil type over the respective initial values. Pednekar (1992) and Santhy *et al.*, (1998) reported that total N content increased in soil in all treatments as compared to its initial status may be attributed due to the application of nitrogenous fertilizers.

Ammonical-N content was found higher in all treatments as compared to nitrate-N content. Singh and Aulakh (2001) reported the similar results. The reason of higher ammonical-N content may be attributed due to accumulation of $\text{NH}_4^+\text{-N}$ in submerged soil was more as compared to $\text{NO}_3^-\text{-N}$ when fertilized, may be due to incomplete inhibition of nitrification in flooded soil because of poor oxygen supply which is more important for nitrification and not necessary for ammonification reaction. As water logging increases oxygen transport decreases and consequently ammonification reaction increases due to its anaerobic nature and nitrification reaction decreases due to its aerobic nature.

Among the various soil types, maximum total-N content was found to be maximum in Coastal saline soil followed by Medium black soil and was minimum in Lateritic soil. The higher value of total N content in Coastal saline soil might be due to high salinity of soil. The low value of total N content in Medium black and Lateritic soil treatments may be due to the fact that soils are percolative in nature and leaching losses of nitrogen and denitrification under submerged conditions.

4.7.2 Effect of different treatments on form of phosphorous in soil at harvest stage of rice crop.

The data regarding the changes in the inorganic P-fractions viz. sal-P (Saloid-P), Al-P, Fe-P, Ca-P, occluded-P, reductant soluble-P and total inorganic-P of soil at harvest of crop as influenced by various treatments is given in Table 36 and 37 (Fig 39) for first and second year of experiment respectively.

4.7.2.1 Saloid-P Fractions:

The data presented in Table 36 and 37, reveals that the saloid-P in soil varied from 7.3 to 14.1 mg kg^{-1} and 5.7 to 13.8 mg kg^{-1} at harvest of rice in first and second year of experiment, respectively and was observed significantly influenced saloid-P fraction under various treatments.

In Lateritic soil, saloid-P content varied from 7.3 to 9.2 mg kg^{-1} during first year of experiment and its content varied from 5.7 to 7.1 mg kg^{-1} in second year of experiment. In Medium black soil, saloid-P content varied from 7.3 to 11.5 mg kg^{-1} during first year of experiment and in second year of experiment, its content varied from 8.1 to 10.5 mg kg^{-1} .

Table 36: Effect of different treatments on form of phosphorous in soil at harvest stage of rice crop (2012)

Treatment	Phosphorous fraction mg kg ⁻¹ (2012)						
	saloid-P	Al-P	Fe-P	Ca-P	occluded-P	Reductant soluble -P	Total inorganic P
T ₁	7.3	88.2	164.4	36.0	78.1	131.7	505.9
T ₂	8.5	96.5	176.1	38.8	82.6	139.9	542.6
T ₃	9.2	98.2	184.1	39.8	85.1	142.4	558.9
T ₄	7.3	55.5	74.0	126.5	44.6	97.6	405.6
T ₅	10.4	59.6	80.4	141.7	48.7	105.4	446.3
T ₆	11.5	61.5	84.8	147	50.8	109.4	465.1
T ₇	11.9	60.1	71.7	129.4	91.5	93.0	457.7
T ₈	12.4	65.6	78.4	131.0	96.6	101.1	485.2
T ₉	14.1	65.8	80.7	135.5	100.4	102.5	499.2
S Em _±	0.55	2.26	2.61	2.42	2.54	2.98	
CD@ 1%	1.59	6.50	7.52	6.97	7.32	8.58	

Table 37: Effect of different treatments on form of phosphorous in soil at harvest stage of rice crop (2013).

2013	Phosphorous fraction mg kg ⁻¹ (2013)						
	saloid-P	Al-P	Fe-P	Ca-P	occluded-P	Reductant soluble-P	Total inorganic P
T ₁	5.7	90.2	161.1	34.4	79.5	128.4	499.4
T ₂	6.3	92.4	172.2	37.3	84.2	139.6	532.1
T ₃	7.1	96.5	176.7	39.2	85.1	142.1	546.8
T ₄	8.1	52.5	77.9	129.5	45.6	99.1	412.7
T ₅	9.8	61.8	82.4	143.3	51.2	103.6	452.3
T ₆	10.5	62.4	86.1	149.7	53.6	106.6	469
T ₇	12.2	56.4	65	125.4	89.5	95.5	444.2
T ₈	13.1	60.4	72.8	132.4	95.3	99.8	474.0
T ₉	13.8	61.2	76.5	133.4	96.0	100.9	481.9
S Em _±	0.56	2.46	2.48	2.29	2.33	2.14	
CD@ 1%	1.62	7.08	7.15	6.59	6.70	6.16	

In Coastal saline soil, saloid-P content varied from 11.9 to 14.1 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 12.2 to 13.8 mg kg⁻¹. The saloid-P was found to be significantly higher (14.1 mg kg⁻¹ in 2012 and 13.8 mg kg⁻¹ 2013) in T₉ (Coastal saline soil+ RDF + Phorate) treatment in the both the years of experiment which was statistically at par with T₈, in the (2012) and and T₇ treatment in (2013).

Application of pesticides (Carbofuron and Phorate) increased the saloid-P content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Combined application of graded dose of fertilizers along with pesticides increased the activities of phosphate solubilizing micro-organisms which secrete a number of organic acids, and hydroxyl acids such as tartaric acids, malonic and malic acids liberated may complex and chelate the PO_4^{3-} ions resulting effective solubilization of organic and native P in soil. The increased in saloid-P may be due to mineralization of organic P and native P results into liberation of organic anions (Sharma *et al.*, 2009). (Sharma *et al.*, 2009). Pattanayak *et al.*, (2009) showed that the rate of P mineralization depends on microbial activity. According to Chisti and Ali (2007), the Phosphate solubilizing micro-organisms leads to increase the inorganic saloid bound P content by accelerating the mineralization process of organic P and native P in soil. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB and phosphatase enzyme activity in the rice rhizosphere soils. The application of pesticides (Carbofuron and Phorate) increased mineralization of organic and native P in pesticides + RDF treated soil by microorganisms showed the increase in saloid-P over RDF only treated soil. (Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported the similar results).

Among the pesticides, the Phorate receiving treatments recorded the highest saloid-P in soil at harvest of rice which were over carbofuron irrespective of soil type. The Phorate was more effective than compared than Carbofuron in contributing to the higher saloid-P content irrespective of soil type may because of increased population sizes and activities of phosphate solubilizing bacteria which in turn influences the transformations of native-P and organic-P in soil. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) and Sharma *et al.*, (2009) quoted the similar results.

Among the various soil types, saloid-P was found to be maximum in Coastal saline followed by Medium black soil and was minimum in Lateritic soil. The higher value of saloid-P content in Coastal saline soil was also quoted by Chattopadhyay and Mandal (1980). The low saloid-P content was recorded in Lateritic soils as compared to Medium black soil. Tamboli and Daftardar (2003) also reported that, the saloid-P content in Medium black soils of Rahuri is higher as compared to Lateritic soils of Konkan region.

It has been observed that the saloid bound-P is the least among the all P fractions which also been reported by authors (Dongale, 1989) in different soil types.

4.7.2.2 Aluminium-bound (Al - P)

The data presented in Table 36 and 37, reveals that the Al - P in soil were observed to be varied from 55.5 to 98.2 mg kg⁻¹ and 52.5 to 96.5mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively.

In Lateritic soil, Al-P content a varied from 88.2 to 98.2 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 90.2 to 96.5 mg kg⁻¹. In Medium black soil, Al-P content varied from 55.5 to 61.5 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 52.5 to 62.4 mg kg⁻¹. In Coastal saline soil, Al-P content varied from 60.1 to 65.8 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 56.4 to 61.2 mg kg⁻¹. The Al - P was found to be significantly superior (98.2 mg kg⁻¹ in 2012 and 96.5 mg kg⁻¹ in 2013) in T₃ (Lateritic soil + RDF + Phorate) treatment in the both the years of experiment which was at par with T₁ and T₂ treatment.

Application of pesticides (Carbofuron and Phorate) increased the Al-P content in the soil at harvest of rice as compared to pesticide untreated soil in all soil type. This may be attributed due to increased activities of microorganisms which helped in mineralization of organic P and hydroxyl acids such as tartaric acids, malonic and malic acids liberated may complex and chelate the PO₄³⁻ ions with Al-P fractions. (Sharma *et al.*, 2009). They further showed that the rate of P mineralization depends on microbial activity. According to Chesti and Ali (2007), the phosphate solubilizing micro-organisms leads to increase the Al-P content by accelerating the mineralization process of organic P and native P in soil. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB and phospahtase enzyme activity in the rice rhizosphere soils.

Among the pesticides, the Phorate receiving treatments recorded the highest Al-P in soil at harvest of rice which was significantly superior over Carbofuron irrespective of soil type. The Phorate was more effective than compared to Carbofuron in contributing to the higher Al-P content irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in mineralization of P was more in case of Phorate as compared to Carbofuron may be due to stimulation was more pronounced with Phorate as compared to Carbofuran resulting in increased population sizes and activities of phosphate solubilizing bacteria which in turn influences the transformations

of native-P and organic-P in soil and increasing Al-P content in soil. Sharma *et al.*, (2009) also reported the similar results.

Among the various soil types, Al-P was observed to be maximum in Lateritic soil followed by Coastal saline soil and was minimum in Medium black soil. The higher value of Al-P fractions in Lateritic soils was also quoted by Dasog *et al.*, (2010). According to Dongale and Kadrekar (1992) the higher Al-P in Lateritic soil might be attributed to the dominance of sesquioxide content and lateritic type of rock from which Lateritic soil was originated. According to Dasog *et al.*, (2010), the soil having low pH contain higher active Aluminium and iron in the soil water system which results into increase in intensity of fixation of added phosphate by aluminium. The higher active Aluminium and iron in the soil may be attributed due to these (Lateritic soil) soils have been developed under high rainfall accompanied by acid hydrolysis and higher amounts of sesquioxides. Tamboli and Daftardar (2003). According to Tamboli and Daftardar (2003) the Al-P is the dominant fraction in Acid Lateritic soil.

Application fertilizers significantly increased the Al-P content irrespective of soil type over the respective initial values of Al-P content. Tamboli and Daftardar (2003) reported that Al-P content increased in soil in all treatments as compared to its initial status may be attributed due to the application of phosphates fertilizers.

4.7.2.3 Iron-bound (Fe-P)

The data presented in Table 36 and 37, reveals that the Fe-P in soil were observed to be varied from 71.7 to 184.1 mg kg⁻¹ and 65.0 to 176.7 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively. It is observed from the data that the Fe-P fraction under various treatments was significantly influenced.

In Lateritic soil, Fe-P content varied from 164.4 to 184.4 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 161.1 to 176.7 mg kg⁻¹. In Medium black soil, Fe-P content varied from 84.8 to 74.0 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 77.9 to 86.1 mg kg⁻¹. In Coastal saline soil, Fe-P content varied from 71.7 to 80.7 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 65 to 76.5 mg kg⁻¹. The Fe-P was found to be significantly higher (184.1 mg kg⁻¹ in 2012 and 176.7 mg kg⁻¹ in 2013) in T₃ (Lateritic soil + RDF + Phorate) treatment in the both the year of experiment which was statistically at par with T₂ treatment.

Application of pesticides (Carbofuron and Phorate) increased the Fe-P content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Combined application of graded dose of fertilizers along with pesticides increased the Fe-P fraction in soil may be attributed due to increased activities of microorganisms which helped in mineralization of organic P. Chesti and Ali (2007) showed that the rate of P mineralization depends on microbial activity. According to Chesti and Ali (2007), the phosphate solubilizing micro-organisms leads to increase the inorganic Fe-P content by accelerating the mineralization process of organic P and native P in soil. Combined application of graded dose of fertilizers along with pesticides increased the activities of phosphate solubilizing micro-organisms which secrete a number of organic acids, which may form chelates resulting effective solubilization of organic and native P in soil. The increased in Fe-P may be due to mineralization of organic P and native P results into liberation of organic anions and hydroxyl acids such as tartaric acids, malonic and malic acids liberated may complex and chelate the PO_4^{3-} ions with Fe-P fractions. Sharma *et al.*, (2009). Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB and phosphahtase enzyme activity in the rice rhizosphere soils. The application of pesticides (Carbofuron and Phorate) increased mineralization of organic and native P in pesticides + RDF 100 percent treated soil by microorganisms showed the increase in Fe-P over RDF 100 percent treated soil. (Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported the similar result). Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported the similar results.

Among the pesticides, the Phorate receiving treatments recorded the highest Fe-P in soil at harvest of rice which were significantly superior over carbofuron. The Phorate was more effective than compared to carbofuron in contributing to the higher Fe-P content in Lateritic soil. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in mineralization of P was more in case of Phorate as compared to Carbofuron may be due to stimulation was more pronounced with Phorate as compared to Carbofuran resulting in increased population sizes and activities of phosphate solubilizing bacteria which in turn influences the transformations of organic-P and native-P in soil and increasing its availability of Fe-P in soil.

Among the various soil types, Fe-P was found to be maximum in Lateritic soil followed by Medium black soil and was minimum in Coastal saline soil. The higher value of Fe-P content in Lateritic soils soil was also quoted by Dasog *et al.*, (2010) These (Lateritic soil) soils have been developed under high rainfall accompanied by acid hydrolysis and higher amounts

of sesquioxides.. According to Dasog *et al.*, (2010) Fe-P content in soil increase with decrease in pH (Lateritic soil) and found higher Fe - P content in low pH (Lateritic soil) soil than neutral and alkali soil. Application of SSP (@ 100 percent RDF) to soil having acidic pH significantly increased the fixation and transformation of native and applied phosphate in soil into iron phosphate. This is attributed to higher concentration of soluble iron at higher pH and thereby increases the fixation of phosphate by it. In the present investigations with addition of P fertilizers (alone or with Pesticides) to soil similar findings were observed. According to Dongale and Kadrekar the higher Fe-P in Lateritic soil might be attributed to the dominance of sesquioxide content and lateritic type of rock from which lateritic soil was originated. Tamboli and Daftardar (2003) also reported the similar results. The low value of Fe-P content was recorded in Medium black and Coastal saline soil treatments as compared to Lateritic soil. Under acid condition of soil (Lateritic) increased solubility of Fe induces the high Fe-P status of soil. Tamboli and Daftardar (2003) reported that the Fe-P content in Medium black soils of Rahuri is lower as compared to Lateritic soils of Konkan region. According to Tamboli and Daftardar (2003) the Fe-P is the dominant fraction in Acid Lateritic soil.

Application of fertilizers significantly increased the Fe - P content of soil irrespective of soil type over the respective initial values. Tamboli and Daftardar (2003), Pednekar (1992) reported that Fe - P content increased in soil in all treatments as compared to its initial status may be attributed due to the application of phosphates fertilizers.

4.7.2.4 Calcium-bound (Ca - P)

The data presented in Table 36 and 37, reveals that the Ca-P in soil were observed to be varied from 36 to 141.7mg kg⁻¹ and 34.4 to 149.7 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively. It is observed from the data that the Ca-P fraction under various treatments was significantly influenced.

In Lateritic soil, Ca-P content varied from 36.0 to 39.8 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 34.4 to 39.2 mg kg⁻¹. In Medium black soil, Ca-P content varied from 126.5 to 147 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 129.5 to 149.7 mg kg⁻¹. In Coastal saline soil, Ca-P content varied from 129.4 to 135.5 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 125.4 to 110 mg kg⁻¹. The Ca-P was found to be significantly superior (147 mg kg⁻¹ in 2012 and 149.7 mg kg⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment in the both year of experiment which was statistically at par with T₅ treatment.

Application of pesticides (Carbofuron and Phorate) increased the Ca - P content in the soil at harvest of rice as compared to pesticide untreated soil. Combined application of graded dose of fertilizers along with pesticides increased the Ca - P fraction in soil may be attributed due to increased activities of microorganisms which helped in mineralization of organic P. According to Chesti and Ali (2007), the phosphate solubilizing micro-organisms leads to increase the inorganic Ca-P content by accelerating the mineralization process of organic P and native P in soil. The increased in Ca - P may be due to mineralization of organic P and native P results into liberation of organic anions and hydroxyl acids such as tartaric acids, malonic and malic acids liberated may complex and chelate the PO_4^{3-} ions with Ca - P fractions. Sharma *et al.*, (2009). Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB and phosphatase enzyme activity in the rice rhizosphere soils. The application of pesticides (Carbofuron and Phorate) increased mineralization of organic and native P in pesticides + RDF treated soil by microorganisms showed the increase in Ca-P over RDF 100 percent only treated soil. (Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) reported the similar results.

The Ca - P fraction was found to be maximum in Medium black soil followed by Coastal saline soil and was minimum in Lateritic soil. Tamboli and Daftardar (2003) also reported that, the Ca-P content in Medium black soils of Rahuri is higher as compared to Lateritic soils of Konkan region. The higher Ca-P content in soil belong to Vertisol was also reported by Niranjana *et al.*, (2012). They also reported that among the all P-fraction, Ca-P is the dominant fraction in Vertisol soil. The higher value of Ca-P in coastal saline soil as compared to Lateritic soil was also reported by Khadtar *et al.*, (1991) They further reported that the Ca is a main salt present in Coastal saline soil, which makes the soil rich in Ca-P. Joshi and Kadrekar (1987) also reported that among the all P-fraction, Ca-P is the dominant fraction in Coastal saline soil of konkan region.

Application of fertilizers significantly increased the Ca-P content of soil the irrespective of soil type over the respective initials values. Tamboli and Daftardar (2003), Pednekar (1992) reported that Ca-P content increased in soil in all treatments as compared to its initial status may be attributed due to the application of phosphates fertilizers.

4.7.2.5 Occluded - P

The data presented in Table 36 and 37, reveals that the occluded - P in soil were observed to be varied from 44.6 to 100.4 mg kg^{-1} and 45.6 to 96.0 mg kg^{-1} among the different treatments at harvest of rice in first and second year of experiment, respectively. It is

observed from the data that the occluded-P fraction under various treatments was significantly influenced.

In Lateritic soil, occluded-P content varied from 78.1 to 85.1 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 79.5 to 85.1 mg kg⁻¹. In Medium black soil, occluded-P content varied from 44.6 to 50.8 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 45.6 to 53.6 mg kg⁻¹. In Coastal saline soil, occluded-P content varied from 91.5 to 100.4 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 89.5 to 96.0 mg kg⁻¹. The occluded-P was found to be significantly superior (100.4 mg kg⁻¹ in 2012 and 96.0 mg kg⁻¹ in 2013) in T₉ (Coastal saline soil + RDF +Phorate) treatment in both years of experiment which was statistically at par with T₇ and T₈ treatments.

Application of pesticides (Carbofuron and Phorate) increased the occluded-P content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type.

Combined application of graded dose of fertilizers along with pesticides increased the occluded-P fraction in soil may be attributed due to increased activities of microorganisms which helped in mineralization of organic P to these inorganic P forms. According to Chesti and Ali (2007), the phosphate solubilizing micro-organisms leads to increase the inorganic occluded-P content by accelerating the mineralization process of organic P and native P in soil. Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB and phosphatase enzyme activity in the rice rhizosphere soils.

The Phorate receiving treatments recorded the higher occluded-P in soil at harvest of rice which were significantly higher over carbofuron. The Phorate was more effective than compared to carbofuron in contributing to the higher occluded-P content irrespective of soil type.

The occluded-P fraction was found to be maximum in Coastal saline soil followed by Lateritic soil and was minimum in Medium black soil. The higher occluded-P fraction in Lateritic soil as compared to Medium black soil was recorded in the present investigation.

Application of fertilisers significantly increased the occluded-P content of soil the irrespective of soil type over the respective initial values. Tamboli and Daftardar (2003), Pednekar (1992) reported that occluded-P content increased in soil in all treatments as compared to its initial status may be attributed due to the application of phosphates fertilizers.

4.7.2.6 Reductant soluble- P

The data presented in Table 36 and 37 reveals that the 93.0 to 142.4 mg kg⁻¹ and 95.5 to 142.1 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively. It is observed that the reductant soluble-P fraction under various treatments was significantly influenced.

In Lateritic soil, reductant soluble-P content varied from 131.7 to 142.4 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 128.4 to 142.1 mg kg⁻¹. In Medium black soil, reductant soluble-P content varied from 97.6 to 109.4 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 99.1 to 106.6 mg kg⁻¹. In Coastal saline soil, reductant soluble-P content varied from 93.0 to 102.5 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 95.5 to 100.9 mg kg⁻¹. The reductant soluble-P was found to be significantly higher in T₃ (Phorate + 100 per cent RDF) treatment (142.4 mg kg⁻¹ in 2012 and 142.1 mg kg⁻¹ in 2013) in the both year of experiment which was statistically at par with T₂ treatment.

Application of pesticides (Carbofuron and Phorate) increased the reductant soluble - P content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Combined application of graded dose of fertilizers along with pesticides increased the reductant soluble-P fraction in soil may be attributed due to increased activities of microorganisms which helped in mineralization of organic P to these inorganic P forms. According to Chesti and Ali (2007), the phosphate solubilizing micro-organisms leads to increase the inorganic reductant soluble-P content by accelerating the mineralization process of organic P and native P in soil. The increased in reductant soluble- P may be due to mineralization of organic P and native P results into liberation of organic anions and hydroxyl acids such as tartaric acids, malonic and malic acids liberated may complex and chelate the PO₄³⁻ ions with Reductant soluble - P fractions (Sharma *et al.*, 2009). Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB and phosphatase enzyme activity in the rice rhizosphere soils. (Das and Mukherjee (2000a, b), Singh and Prasad (1991), Das and Mukherjee (1998b) and Das (1997) reported that the application of pesticides (Carbofuron and Phorate) increased mineralization of organic and native P in pesticides + RDF 100 percent treated soil by microorganisms showed the increase in P mineralization over RDF 100 percent only (without pesticides). Das and Mukherjee (1998b) reported the similar results. They all found that mineralization of P increased due to the application of insecticides in soil under rice crop.

Application of pesticides (Carbofuron and Phorate) increased the reductant soluble-P content in the soil at harvest of rice as compared to pesticide untreated soil. Combined

application of graded dose of fertilizers along with pesticides increased the reductant soluble-P fraction in soil may be attributed due to increased activities of microorganisms which helped in mineralization of organic P to these inorganic P forms. Chesti and Ali (2007), showed that the rate of P mineralization depends on microbial activity. According to Chesti and Ali (2007), the phosphate solubilizing micro-organisms leads to increase the inorganic reductant soluble-P content by accelerating the mineralization process of organic P and native P in soil. The increased in Reductant soluble-P may be due to mineralization of organic P and native P results into liberation of organic anions and hydroxyl acids such as tartaric acids, malonic and malic acids liberated may complex and chelate the PO_4^{3-} ions with Reductant soluble-P fractions (Sharma *et al.*, 2009). Das *et al.*, (2003) reported that application of insecticides (Phorate, Carbofuron) at their recommended dose stimulated the population of PSB and phosphatase enzyme activity in the rice rhizosphere soils.

Among the pesticides, the Phorate receiving treatments recorded the higher reductant soluble-P in soil at harvest of rice which were significantly superior over Carbofuron irrespective of soil type. The Phorate was more effective than compared to Carbofuron in contributing to the higher P mineralization irrespective of soil type. Das and Mukherjee (1994), Das and Mukherjee (1998b) and Das *et al.*, (2003) also showed that the increased in mineralization of P was more in case of Phorate as compared to Carbofuron may be due to stimulation was more pronounced with Phorate as compared to Carbofuran resulting in increased population sizes and activities of phosphate solubilizing bacteria which in turn influences the transformations of plant nutrient elements in soil and increasing its availability of reductant soluble-P.

The reductant soluble-P fraction was found to be maximum in Lateritic soils followed by Medium black soil and was minimum in Coastal saline soils. The higher values of reductant soluble-P in Lateritic soil was also reported by Dongale (1993) which was attributed to higher content higher content of sesquioxides. Tamboli and Daftardar (2003) reported that reductant soluble-P of Vertisol of Rahuri is low (47.7 mg kg^{-1}) as compared to reductant soluble-P (63.45 mg kg^{-1}), of Lateritic soils of konkan region. According to Dasog *et al.*, (2010) reductant soluble-P content in soil increase with decrease in pH (Lateritic soil) and found higher reductant soluble-P content in low pH (Lateritic soil) than neutral and alkali soil.

Application of fertilizers significantly increased the reductant soluble-P content irrespective of soil type over the respective initial values. Tamboli and Daftardar (2003), Pednekar (1992) reported that reductant soluble-P content increased in soil in all treatments

as compared to its initial status may be attributed due to the application of phosphates fertilizers.

4.7.2.6 Total inorganic - P

A total inorganic-P fraction is the sum of fractions viz. saloid-P, Ca-P, Al-P, Fe-P, occluded-P and reductant soluble-P. The data presented in Table 36 and 37 reveals that Total inorganic-P content in soil varied from 405.6 to 558.9 mg kg⁻¹ and 412.7 to 546.8 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively. It is observed from the data that the total inorganic-P fraction under various treatments was significantly influenced.

In Lateritic soil, total inorganic-P content varied from 505.9 to 558.9 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 499.4 to 546.8 mg kg⁻¹. In Medium black soil, total inorganic-P content varied from 405.6 to 465.1 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 412.7 to 469 mg kg⁻¹. In Coastal saline soil, total inorganic-P content varied from 457.7 to 499.2 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 444.2 to 481.9 mg kg⁻¹.

The total inorganic-P was found to be higher in (558.9 mg kg⁻¹ in 2012 and 546.8 mg kg⁻¹ in 2013) in T₃ (Lateritic soil+ RDF+ Phorate) treatment in both the years of experiment.

The total inorganic P was found to be maximum in Lateritic soil followed by Medium black soil and was minimum in Coastal saline soil in the present study.

4.7.3 Effect of different treatments on form of potassium in soil at harvest stage of rice crop

The data regarding the changes in the inorganic potassium fractions water soluble-K, exchangeable-K, non-exchangeable-K, and available-K (water soluble-K+exchangeable-K) of soil under rice crop at harvest stage as influenced by various treatments are given in Table 38 and Table 39 (Fig 40) for first and second year of experiment and discussed below.

Table 38: Effect of different treatments on form of potassium in soil at harvest stage of rice crop (2012)

Treatment	Fractions of potassium 2012 (mg kg ⁻¹)			
	Water soluble-K	Exch-K	Non. Exch-K	Available. K (water sol+Exch-K)
T ₁	4.8	95.2	361.4	100
T ₂	5.2	96.13	372.8	101.3

T ₃	5.8	96.36	378.9	102.1
T ₄	6.1	105.3	409.5	111.4
T ₅	7.93	111.5	424.8	119.4
T ₆	8.4	112.7	427.8	121.1
T ₇	98.1	305.9	471.2	404.0
T ₈	98.8	307.5	480.5	406.3
T ₉	99.1	308.0	483.4	407.2
S Em ₊	0.66	1.5	1.46	
CD@ 1%	1.92	4.40	4.21	

Table.39: Effect of different treatments on form of potassium in soil at harvest stage of rice crop (2013).

Treatment	Fractions of potassium 2013 (mg kg ⁻¹)			
	Water soluble-K	Exch-K	Non. Exch-K	Available. K (water sol.+ Exch-K)
T ₁	3.2	93.86	365.2	97.06
T ₂	3.8	94.46	374.8	98.2
T ₃	4.2	94.5	381	98.7
T ₄	5.3	96.66	401.8	101.9
T ₅	6.0	98.56	417.5	104.5
T ₆	6.4	98.9	423.7	105.3
T ₇	90.1	310.6	463.7	400.7
T ₈	92.4	311.4	469.8	403.8
T ₉	92.9	312	472.5	404.9
S Em ₊	0.48	1.05	1.53	
CD@ 1%	1.4	3.04	4.4	

4.7.3.1 Water soluble - K fractions:

The data reveals that the water soluble-K in soil is observed to be vary from 4.8 to 99.1 mg kg⁻¹ and 3.2 to 92.9 mg kg⁻¹ among the different treatments at harvest of rice in the first and second year of experiment, respectively.

In Lateritic soil, water soluble-K content varied from 4.8 to 5.8 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 3.2 to 4.2 mg kg⁻¹. In Medium black soil, water soluble-K content varied from 6.1 to 8.4 mg kg⁻¹ during first year of experiment however in second year of experiment, its content varied from 5.3 to 6.4 mg kg⁻¹.

¹. In Coastal saline soil, water soluble-K content varied from 98.1 to 99.1 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 90.1 to 92.9 mg kg⁻¹. The water soluble-K was found to be significantly superior (99.1 and 92.9 mg kg⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) during both the years of experiment and which was statistically at par with T₈ and T₇ treatment in the first years of experiment and with T₈ in the second year of experiment.

Application of K fertilizers through RDF only with or without pesticides significantly increased the water soluble-K content irrespective of soil type over the respective initials values. Pednekar (1992) reported that water soluble - K content increased in soil as compared to its initial status may be attributed due to the application of K fertilizers. A small portion of applied K was transformed as water soluble-K and increased the water soluble-K content irrespective of soil type. Setia and Sharma (2004).

Combined application of graded dose of fertilizers along with pesticides increased the water soluble-K fraction in soil may be attributed due to increased activities of microorganisms. Bagal (2009) reported that application of pesticides increased the available potassium (Water soluble + exch. K) in soil under rice crop. The Phorate receiving treatments recorded the higher water soluble-K in soil than Carbofuron.

Among the various soil types, water soluble-K was observed to be maximum in Coastal saline (90.1 to 99.1 mg kg⁻¹) followed by Medium black (5.3 to 7.9 mg kg⁻¹) and was lowest in Lateritic soil (3.2 to 5.8 mg kg⁻¹). The native higher water soluble-K content in Coastal saline soil leads to higher values. The water soluble-K in Coastal saline was found to be several times higher than the other two soil types because of the soils being saline in nature. Addition of potassium as major accumulated salts through sea water tides source could be the other cause of higher water source K values. (Joshi 1985). Several times higher water soluble-K content in coastal saline soil was also observed and recorded by earlier worker (Mali 1989) . The low water soluble-K content in Lateritic soils treatments might be due to low capacity to retain cation as a result of low CEC and clay percentage. Similar observations were as regards to water soluble-K content in soil has been reported by Kadrekar (1977).

The water soluble-K fraction is the least among all K fractions as reported by many authors (Kadrekar (1977) and (Mali 1989) in different soil types.

4.7.3.2 Exchangeable - K fractions:

The data presented in Table 38 and Table 39 reveals that the exchangeable-K in soil is observed vary from 95.2 to 308.0 mg kg⁻¹ and 93.86 to 312.0 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively.

Exchangeable-K content in Lateritic soil varied from 95.2 to 96.36 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 93.8 to 94.5 mg kg⁻¹. In Medium black soil, exchangeable-K content varied from 105.3 to 112.7 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 96.6 to 98.9 mg kg⁻¹. In Coastal saline soil, exchangeable-K content varied from 305.9 to 308.0 mg kg⁻¹ during first year of experiment while in second year of experiment, its content varied from 310.6 to 312 mg kg⁻¹. The exchangeable-K was found to be significantly superior (308.0 and 312.0 mg kg⁻¹) in T₉ (Coastal saline soil + RDF + Phorate) treatment in the both the years of experiment which was statistically at par with T₇ and T₈ treatment.

Application of fertilizers with or without pesticides significantly increased the exchangeable-K content irrespective of soil type over the respective initial values of exchangeable-K content. Pednekar (1992) reported that exchangeable-K content increased in soil in all treatments as compared to its initial status may be attributed due to the application of fertilizers. A small portion of applied K was transformed as exchangeable-K and increases the exchangeable-K content irrespective of soil type over the respective initial (Setia and Sharma 2004).

Application of pesticides (Carbofuron and Phorate) increased the exchangeable-K content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Similar observations were quoted by Bagal (2009). Combined application of graded dose of fertilizers along with pesticides increased the exchangeable-K fraction in soil which may be attributed due to increased activities of microorganisms.

Among the pesticides, the Phorate receiving treatments recorded the highest exchangeable-K in soil at harvest of rice which was significantly superior over Carbofuron irrespective of soil type.

Among the various soil types, exchangeable-K is observed to be order of higher in Coastal saline (305.9 to 312.0 mg kg⁻¹) followed by Medium black (96.66 to 112.7 mg kg⁻¹) and found minimum in Lateritic soil (93.86 to 96.36 mg kg⁻¹). The higher value of exchangeable-K content in Coastal saline soil was also quoted by Kadrekar (1977). Exchangeable-K content in soil increases with increase in electrical conductivity or salinity. The exchangeable-K in Coastal saline soil was found to be higher than other two soils might be because of the soils being

saline and contain potassium as major salts added through sea water source continuously and makes the soil containing potassium rich (Joshi 1985).

The results suggest that capacity of soil to retain loosely bound the exchangeable-K is depending upon finer particles viz., clay percent. As clay percent increased the exchangeable-K content also increased in different soil types.

4.7.3.3 Non Exchangeable- K Fractions:

The data presented in Table 38 and Table 39, reveals that the non exchangeable-K in soil is observed to be vary from 361.4 to 483.4 mg kg⁻¹ and 365.2 to 472.5 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively.

In Lateritic soil, non-exchangeable-K content varied from 361.4 to 378.9 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 365.2 to 381 mg kg⁻¹. In Medium black soil, non exchangeable-K content varied from 409.5 to 427.8 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 401.8 to 423.7 mg kg⁻¹. In Coastal saline soil, non exchangeable-K content varied from 471.2 to 483.4 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 463.7 to 472.5 mg kg⁻¹. The non exchangeable-K was found to be significantly superior (483.40 mg kg⁻¹ in 2012 and 472.5 mg kg⁻¹ in 2013) in T₉ (Coastal saline soil+ RDF + Phorate) treatment in the both the years was statistically at par with T₈ treatment.

Application of K fertilizers (100 percent RDF only) with or without pesticides significantly increased the non exchangeable-K content irrespective of soil type over the respective initials values of non exchangeable-K content. Pednekar (1992), and Dhar *et al.*, (2009) reported that nonexchangeable - K content increased in soil in K fertilizers treated treatments as compared to its initial status may be attributed due to the transformation of applied of K fertilizers into non-exchangeable fraction of potassium. A large portion of applied K was transformed as non exchangeable-K and increased the non exchangeable-K content irrespective of soil type over the respective initials. Setia and Sharma (2004). The largest fraction of applied K was transformed as non-exchangeable form followed by water soluble and exchangeable-K.

Application of pesticides (Carbofuron and Phorate) increased the non exchangeable-K content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Combined application of graded dose of fertilizers along with pesticides increased the

non exchangeable- K fraction in soil may be attributed due to increased activities of microorganisms.

Among the pesticides, the Phorate receiving treatments recorded the highest non exchangeable-K in soil at harvest of rice which was significantly superior over Carbofuron irrespective of soil type. The Phorate was more effective than compared to Carbofuron in contributing to the higher non exchangeable-K content irrespective of soil type.

Among the various soil types, non exchangeable-K is observed to be maximum in Coastal saline (463.7 to 483.4 mg kg⁻¹) followed by Medium black (401.8 to 427.8 mg kg⁻¹) and was minimum in Lateritic soil (361.4 to 381.0 mg kg⁻¹). The nonexchangeable-K in Coastal saline soil was found to be higher than other two soils because of the soils being saline and contain potassium as major salts added through sea water source continuously and makes soil containing potassium rich. (Joshi 1985). Similar observations were also recorded by earlier worker (Mali 1989). Non exchangeable-K content in soil increases with increase in electrical conductivity or salinity (Coastal saline) and found higher non exchangeable-K content in coastal saline soil than non saline normal soil. The higher non exchangeable-K content in Coastal saline soil may be due to the sea water tidal action.

4.7.3.4 Available - K Fractions:

Available-K fraction is the sum of two K fractions viz., water soluble-K fraction and exchangeable-K fraction of potassium. The data presented in Table 38 and Table 39, reveals that the available K in soil were observed to be vary from 95.2 to 308.0 mg kg⁻¹ and 93.86 to 312.0 mg kg⁻¹ among the different treatments at harvest of rice in first and second year of experiment, respectively.

In Lateritic soil, available-K content varied from 100 to 102.1 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 97.06 to 98.7 mg kg⁻¹. In Medium black soil, available-K content varied from 111.4 to 121.1 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 101.9 to 105.3 mg kg⁻¹. In Coastal saline soil, available-K content varied from 404.0 to 407.2 mg kg⁻¹ during first year of experiment and in second year of experiment, its content varied from 400.2 to 404.9 mg kg⁻¹. The available-K was found higher (407.2 mg kg⁻¹ in 2012 and 312 mg kg⁻¹ in 2013) in T₉ (Coastal saline soil + RDF +Phorate) during both the years of experiment .

Application of K fertilizers (100 percent RDF only) with or without pesticides significantly increased the available-K content irrespective of soil type over the respective initials values of available-K content. Pednekar (1992) and Dhar *et al.*, (2009) reported that

available-K content increased in soil in all treatments as compared to its initial status may be attributed due to the application of K fertilizers. A large portion of applied K was transformed as available - K and increases the non exchangeable-K content irrespective of soil type over the respective initials. Setia and Sharma (2004).

Application of pesticides (Carbofuron and Phorate) increased the available-K content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Similar observations were quoted by Bagal (2009). Combined application of graded dose of fertilizers along with pesticides increased the available-K fraction in soil may be attributed due to increased activities of microorganisms.

Among the pesticides, the Phorate receiving treatments recorded the highest available-K in soil at harvest of rice which were higher than Carbofuron irrespective of soil type. The Phorate was more effective than compared to Carbofuron in contributing to the higher available-K content irrespective of soil type.

Among the various soil types, available-K ranking was observed to be maximum in Coastal saline (400.7 to 407.2 mg kg⁻¹) followed by Medium black (111.4 to 121.1 mg kg⁻¹) and was minimum in Lateritic soil (97.06 to 102.1 mg kg⁻¹). The available potassium of Coastal saline soil found highest as compared to Lateritic soil and Medium black soil. According to Joshi and Kadrekar (1987) the higher available potassium value in Coastal saline soil associated with high salinity, indicating that potassium from the sea water might be one of the major source contributing to the higher soil potash. Available-K content in soil increase with increase in electrical conductivity or salinity and found higher available-K content in Coastal saline soil than non saline normal soil.

Among the various fractions of potassium studied in Lateritic soil under rice crop, the distribution of fractions is observed in decreasing order viz. non exchangeable-K, (361.4-381.0mgkg⁻¹), available-K (water soluble-K+exch.-K) (97.06 to 102.1 mg kg⁻¹), exchangeable-K (93.8 to 96.3 mg kg⁻¹), water soluble-K (3.2 to 5.8 mg kg⁻¹).

Among the various fractions of potassium studied in Medium black soil under rice crop, the distribution of fractions is observed in decreasing order viz. non exch-K (401.8 to 427.8 mg kg⁻¹), available-K (water soluble-K + exch-K) (101.9 to 121.1 mg kg⁻¹), exch-K (96.6 to 112.7 mg kg⁻¹), water soluble-K (3.2 to 5.8 mg kg⁻¹).

Among the various fractions of potassium studied in Coastal saline soil under rice crop the distribution of fractions is observed in decreasing order viz. none exch-K (463.7 to

483.4 mg kg⁻¹, available-K (water soluble-K + exch-K) (400.7 to 407.2 mg kg⁻¹), exch-K (305.9 to 312.0 mg kg⁻¹), water soluble-K (90.1 to 99.1 mg kg⁻¹).

4.8 Correlation between various physico-chemical properties with available macronutrient and pesticides at different growth stages of rice.

In order to understand the relation between various physico-chemical properties with available primary nutrients (available nitrogen, available P₂O₅ and available K₂O) and pesticide residues at different growth stages (30, 60, 90 DAT and at harvest stage) of rice, the correlation coefficients were worked out. The data regarding to the correlation is presented in Table 40 and 41 for first and second year of the experiment respectively.

4.8.1. Correlation between various physico-chemical properties with available nitrogen in soil under rice crop

At 30DAT, a significant and positive relationship of electrical conductivity with available nitrogen was seen during both the years of experiment ($r = 0.449^*$ in 2012 and $r = 0.472^*$ in 2013). The pH was found non-significant and negatively correlated with available nitrogen in the first year of experiment and was observed to be positively correlated in the second year of experiment.

At 60 DAT, the available nitrogen was positively correlated with sand, infiltration rate, EC and organic carbon and was negatively correlated with clay pH CEC and silt during the first year of experiment. In the second year of experiment available nitrogen was positively correlated with clay, pH, EC and CEC and was negatively correlated with sand silt, IR, and OC.

At 90 DAT, a highly significant and positive relationship of clay, pH, electrical conductivity and CEC with available nitrogen was seen during both the years of experiment ($r = 0.86^{**}$ for clay, $r = 0.704^{**}$ for pH, $r = 0.873^{**}$ for EC, $r = 0.765^{**}$ for CEC in the first year of experiment and $r = 0.608^{**}$ for silt, $r = 0.597^{**}$ for clay, $r = 0.651^{**}$ for pH, $r = 0.645^{**}$ for CEC in the second year of experiment). The available nitrogen was highly significant and positively correlated with EC ($r = 0.873^{**}$) in the first year of experiment and was significant and positively correlated with EC ($r = 0.43^*$) during the second year of experiment. A highly significant and negative relationship of OC, infiltration rate and sand with available nitrogen was seen during both the year of experiment ($r = -0.703^{**}$ for sand, $r = -0.813^{**}$ for infiltration rate, $r = -0.844^{**}$ for OC in the first year of experiment and $r = -0.652^{**}$ for sand, $r = -0.633^{**}$ for infiltration rate, $r = -0.615^{**}$ for OC in the second year of experiment).

At harvest, a highly significant and positive relationship of clay and electrical conductivity with available nitrogen was seen during both the year of experiment ($r = 0.712^{**}$ for clay, $r = 0.928^{**}$ for EC in the first year of experiment and $r = 0.716^{**}$ for clay, $r = 0.932^{**}$ for EC in the second year of experiment). A significant and positive relationship of CEC with available nitrogen was seen during both the years of experiment. ($r = 0.501^*$ for CEC in 2012 and $r = 0.505^*$ for CEC in 2013). A highly

Table 40. Coerrelatonship between primary nutrient and pesticides with physico-chemical properties of soil. (2012).

<u>2012</u>	<u>N 30</u>	<u>N 60</u>	<u>N 90</u>	<u>N AH</u>	<u>P 30</u>	<u>P 60</u>	<u>P 90</u>	<u>P AH</u>	<u>K 30</u>	<u>K 60</u>	<u>K 90</u>	<u>K AH</u>	<u>Pest 30</u>	<u>Pest 60</u>	<u>Pest 90</u>	<u>Pest AH</u>
<u>Sand</u>	<u>0.042 ns</u>	<u>0.171 ns</u>	<u>-0.703 **</u>	<u>-0.393 ns</u>	<u>-0.968 **</u>	<u>-0.973 **</u>	<u>-0.982 **</u>	<u>-0.993 **</u>	<u>-0.681 **</u>	<u>-0.681 **</u>	<u>-0.684 **</u>	<u>-0.676 **</u>	<u>0.034 ns</u>	<u>0.211 ns</u>	<u>0.233 ns</u>	<u>0.156 ns</u>
<u>silt</u>	<u>-0.27 ns</u>	<u>-0.215 ns</u>	<u>0.46 *</u>	<u>0.044 ns</u>	<u>0.85 **</u>	<u>0.892 **</u>	<u>0.871 **</u>	<u>0.916 **</u>	<u>0.371 ns</u>	<u>0.371 ns</u>	<u>0.374 ns</u>	<u>0.365 ns</u>	<u>0.068 ns</u>	<u>0.109 ns</u>	<u>0.056 ns</u>	<u>0.164 ns</u>
<u>clay</u>	<u>0.212 ns</u>	<u>-0.098 ns</u>	<u>0.86 **</u>	<u>0.712 **</u>	<u>0.946 **</u>	<u>0.908 **</u>	<u>0.951 **</u>	<u>0.922 **</u>	<u>0.913 **</u>	<u>0.913 **</u>	<u>0.915 **</u>	<u>0.911 **</u>	<u>-0.142 ns</u>	<u>-0.532 **</u>	<u>-0.515 *</u>	<u>-0.484 *</u>
<u>IR</u>	<u>-0.111 ns</u>	<u>0.13 ns</u>	<u>-0.813 **</u>	<u>-0.594 **</u>	<u>-0.975 **</u>	<u>-0.954 **</u>	<u>-0.984 **</u>	<u>-0.97 **</u>	<u>-0.835 **</u>	<u>-0.835 **</u>	<u>-0.838 **</u>	<u>-0.832 **</u>	<u>0.099 ns</u>	<u>0.408 *</u>	<u>0.407 *</u>	<u>0.357 ns</u>
<u>pH</u>	<u>-0.042 ns</u>	<u>-0.171 ns</u>	<u>0.704 **</u>	<u>0.394 ns</u>	<u>0.967 **</u>	<u>0.972 **</u>	<u>0.982 **</u>	<u>0.992 **</u>	<u>0.682 **</u>	<u>0.681 **</u>	<u>0.684 **</u>	<u>0.677 **</u>	<u>-0.035 ns</u>	<u>-0.214 ns</u>	<u>-0.235 ns</u>	<u>-0.159 ns</u>
<u>EC</u>	<u>0.449 *</u>	<u>0 ns</u>	<u>0.873 **</u>	<u>0.928 **</u>	<u>0.75 **</u>	<u>0.674 **</u>	<u>0.744 **</u>	<u>0.677 **</u>	<u>0.999 **</u>	<u>0.999 **</u>	<u>0.999 **</u>	<u>0.999 **</u>	<u>-0.232 ns</u>	<u>-0.78 **</u>	<u>-0.726 **</u>	<u>-0.751 **</u>
<u>OC</u>	<u>-0.17 ns</u>	<u>0.111 ns</u>	<u>-0.844 **</u>	<u>-0.665 **</u>	<u>-0.962 **</u>	<u>-0.931 **</u>	<u>-0.968 **</u>	<u>-0.946 **</u>	<u>-0.884 **</u>	<u>-0.884 **</u>	<u>-0.886 **</u>	<u>-0.881 **</u>	<u>0.124 ns</u>	<u>0.481 *</u>	<u>0.471 *</u>	<u>0.432 *</u>
<u>CEC</u>	<u>0.037 ns</u>	<u>-0.151 ns</u>	<u>0.765 **</u>	<u>0.501 *</u>	<u>0.978 **</u>	<u>0.969 **</u>	<u>0.989 **</u>	<u>0.987 **</u>	<u>0.766 **</u>	<u>0.766 **</u>	<u>0.769 **</u>	<u>0.762 **</u>	<u>-0.069 ns</u>	<u>-0.318 ns</u>	<u>-0.328 ns</u>	<u>-0.264 ns</u>

Table 41: Coerrelatonship between primary nutrient and pesticides with physico-chemical properties of soil. (2013)

<u>2013</u>	<u>N 30</u>	<u>N 60</u>	<u>N 90</u>	<u>N AH</u>	<u>P 30</u>	<u>P 60</u>	<u>P 90</u>	<u>P AH</u>	<u>K 30</u>	<u>K 60</u>	<u>K 90</u>	<u>K AH</u>	<u>Pest 30</u>	<u>Pest 60</u>	<u>Pest 90</u>	<u>Pest AH</u>
<u>Sand</u>	<u>-0.027 ns</u>	<u>-0.008 ns</u>	<u>-0.652 **</u>	<u>-0.396 ns</u>	<u>-0.941 **</u>	<u>-0.944 **</u>	<u>-0.971 **</u>	<u>-0.988 **</u>	<u>-0.666 **</u>	<u>-0.681 **</u>	<u>-0.668 **</u>	<u>-0.666 **</u>	<u>0.044 ns</u>	<u>0.174 ns</u>	<u>0.206 ns</u>	<u>0.047 ns</u>
<u>silt</u>	<u>-0.194 ns</u>	<u>-0.006 ns</u>	<u>0.608 **</u>	<u>0.047 ns</u>	<u>0.79 **</u>	<u>0.826 **</u>	<u>0.837 **</u>	<u>0.898 **</u>	<u>0.352 ns</u>	<u>0.371 ns</u>	<u>0.354 ns</u>	<u>0.353 ns</u>	<u>0.055 ns</u>	<u>0.112 ns</u>	<u>0.046 ns</u>	<u>0.28 ns</u>
<u>clay</u>	<u>0.264 ns</u>	<u>0.02 ns</u>	<u>0.597 **</u>	<u>0.716 **</u>	<u>0.96 **</u>	<u>0.927 **</u>	<u>0.965 **</u>	<u>0.933 **</u>	<u>0.905 **</u>	<u>0.913 **</u>	<u>0.906 **</u>	<u>0.905 **</u>	<u>-0.147 ns</u>	<u>-0.463 *</u>	<u>-0.452 *</u>	<u>-0.4 ns</u>
<u>IR</u>	<u>-0.171 ns</u>	<u>-0.016 ns</u>	<u>-0.633 **</u>	<u>-0.598 **</u>	<u>-0.972 **</u>	<u>-0.954 **</u>	<u>-0.988 **</u>	<u>-0.975 **</u>	<u>-0.824 **</u>	<u>-0.835 **</u>	<u>-0.826 **</u>	<u>-0.824 **</u>	<u>0.106 ns</u>	<u>0.351 ns</u>	<u>0.358 ns</u>	<u>0.261 ns</u>
<u>pH</u>	<u>0.028 ns</u>	<u>0.007 ns</u>	<u>0.651 **</u>	<u>0.398 ns</u>	<u>0.941 **</u>	<u>0.944 **</u>	<u>0.97 **</u>	<u>0.987 **</u>	<u>0.666 **</u>	<u>0.681 **</u>	<u>0.668 **</u>	<u>0.667 **</u>	<u>-0.045 ns</u>	<u>-0.177 ns</u>	<u>-0.208 ns</u>	<u>-0.051 ns</u>
<u>EC</u>	<u>0.472 *</u>	<u>0.03 ns</u>	<u>0.43 *</u>	<u>0.932 **</u>	<u>0.806 **</u>	<u>0.74 **</u>	<u>0.784 **</u>	<u>0.703 **</u>	<u>0.999 **</u>	<u>0.999 **</u>	<u>0.999 **</u>	<u>0.999 **</u>	<u>-0.231 ns</u>	<u>-0.69 **</u>	<u>-0.635 **</u>	<u>-0.708 **</u>
<u>OC</u>	<u>-0.226 ns</u>	<u>-0.019 ns</u>	<u>-0.615 **</u>	<u>-0.67 **</u>	<u>-0.969 **</u>	<u>-0.942 **</u>	<u>-0.979 **</u>	<u>-0.954 **</u>	<u>-0.874 **</u>	<u>-0.884 **</u>	<u>-0.876 **</u>	<u>-0.875 **</u>	<u>0.13 ns</u>	<u>0.417 *</u>	<u>0.413 *</u>	<u>0.343 ns</u>
<u>CEC</u>	<u>0.102 ns</u>	<u>0.011 ns</u>	<u>0.645 **</u>	<u>0.505 *</u>	<u>0.963 **</u>	<u>0.955 **</u>	<u>0.986 **</u>	<u>0.988 **</u>	<u>0.753 **</u>	<u>0.766 **</u>	<u>0.755 **</u>	<u>0.753 **</u>	<u>-0.078 ns</u>	<u>-0.27 ns</u>	<u>-0.289 ns</u>	<u>-0.161 ns</u>

significant and negative relationship of IR and OC with available nitrogen was seen during both the years of experiment ($r = -0.594^{**}$ for IR, $r = -0.665^{**}$ for OC in 2012 and $r = -0.598^{**}$ for infiltration rate, $r = -0.67^{**}$ for OC in the second year of experiment). The available nitrogen was non-significant and positively correlated with silt, pH and was negatively correlated with sand during the both years of experiment.

In the present study the available nitrogen in soil had a significant relationship with electrical conductivity. Dabke (1987) and Pednekar (1992) also observed the positive significant relationship between electrical conductivity and available nitrogen in soils of konkan region. The relationship of pH with available nitrogen was found non-significant except in available nitrogen. Pednekar (1992) also reported that the pH had non-significant relation with available nitrogen.

4.8.2 Correlation between various physico-chemical properties with available phosphorous in soil under rice crop.

At 30DAT, a significant relationship of available P_2O_5 with all physic-chemical properties was seen during both the years of experiment. A highly significant and positive relationship of silt, clay, pH, electrical conductivity and CEC with available P_2O_5 was observed ($r = 0.85^{**}$ for silt, $r = 0.946$ for clay, $r = 0.967^{**}$ for pH, $r = 0.75^{**}$ for EC, $r = 0.978^{**}$ for CEC in 2012 and $r = 0.79^{**}$ for silt, $r = 0.96^{**}$ for clay, $r = 0.941^{**}$ for pH, $r = 0.806^{**}$ for EC, $r = 0.963^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available P_2O_5 was seen during the both the years of experiments $r = -0.968^{**}$ for sand, $r = -0.975^{**}$ for infiltration rate, $r = -0.962^{**}$ for OC in the first year of experiment $r = -0.941^{**}$ for sand, $r = -0.972^{**}$ for infiltration rate, $r = -0.969^{**}$ for OC in the second year of experiment.

At 60DAT, a significant relationship of available P_2O_5 with all physic-chemical properties was seen during both the year of experiment. A highly significant and positive relationship of silt, clay, pH, electrical conductivity and CEC with available P_2O_5 ($r = 0.892^{**}$ for silt, $r = 0.908^{**}$ for clay, $r = 0.972^{**}$ for pH, $r = 0.674^{**}$ for EC, $r = 0.969^{**}$ for CEC in 2012 and $r = 0.826^{**}$ for silt, $r = 0.927^{**}$ for clay, $r = 0.944^{**}$ for pH, $r = 0.74^{**}$ for EC, $r = 0.955^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available P_2O_5 was seen during the both the years of experiments ($r = -$

0.973** for sand, $r = 0.954^{**}$ for infiltration rate, $r = -0.937^{**}$ for OC in 2012, $r = -0.944^{**}$ for sand, $r = -0.954^{**}$ for infiltration rate, $r = -0.942^{**}$ for OC in 2013).

At 90DAT a significant relationship of available P_2O_5 with all physicochemical properties was seen during both the years of experiment. A highly significant and positive relationship of silt, clay, pH, electrical conductivity and CEC with available P_2O_5 was seen ($r = 0.871^{**}$ for silt, $r = 0.951^{**}$ for clay, $r = 0.982^{**}$ for pH, $r = 0.744^{**}$ for EC, $r = 0.989^{**}$ for CEC in 2012 and $r = 0.837^{**}$ for silt, $r = 0.965^{**}$ for clay, $r = 0.97^{**}$ for pH, $r = 0.784^{**}$ for EC, $r = 0.986^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available P_2O_5 was seen during the both the year of experiments ($r = 0.982^{**}$ for sand, $r = 0.984^{**}$ for infiltration rate, $r = 0.968^{**}$ for OC in 2012, $r = 0.971^{**}$ for sand, $r = 0.988^{**}$ for infiltration rate, $r = 0.979^{**}$ for OC in 2013.)

At harvest, a significant relationship of available P_2O_5 with all physicochemical properties was seen during both the year of experiment. A highly significant and positive relationship of silt, clay, pH, electrical conductivity and CEC with available P_2O_5 was found out ($r = 0.916^{**}$ for silt, $r = 0.922^{**}$ for clay, $r = 0.992^{**}$ for pH, $r = 0.677^{**}$ for EC, $r = 0.987^{**}$ for CEC in 2012 and $r = 0.898^{**}$ for silt, $r = 0.933^{**}$ for clay, $r = 0.987^{**}$ for pH, $r = 0.703^{**}$ for EC, $r = 0.988^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available P_2O_5 was seen during the both the year of experiments ($r = -0.993^{**}$ for sand, $r = -0.997^{**}$ for infiltration rate, $r = -0.946^{**}$ for OC in 2012, $r = -0.988^{**}$ for sand, $r = -0.975^{**}$ for infiltration rate, $r = -0.954^{**}$ for OC in 2013).

Overall results showed that the sand, OC and infiltration rate recorded significant negative correlation with available P_2O_5 . Lungmuana *et al.*, (2012) also showed that available P_2O_5 had negative correlation with sand content and organic carbon of soil. The results in present investigation showed that silt and clay content had a highly significant positive relationship with available P_2O_5 in soil. Lungmuana *et al.*, (2012) also showed that available P_2O_5 had significant positive relationship with silt and clay content in soil. The results in present investigation indicated that pH, EC and cation exchange capacity had

a highly significant positive relationship with available P_2O_5 in soil. Das *et al.*, (1991) and Lungmuana *et al.*, (2012) also showed that available P_2O_5 had significant positive relationship with available P_2O_5 in soil with pH, EC and cation exchange capacity of soil.

4.8.3 Correlation between various physico-chemical properties with available potassium in soil under rice crop.

At 30DAT, a significant relationship of available K_2O with all physico-chemical properties except silt was seen during both the year of experiment. A highly significant and positive relationship of clay, pH, electrical conductivity and CEC with available K_2O was observed ($r = 0.913^{**}$ for clay, $r = 0.682^{**}$ for pH, $r = 0.999^{**}$ for EC, $r = 0.766^{**}$ for CEC in 2012 and $r = 0.905^{**}$ for clay, $r = 0.666^{**}$ for pH, $r = 0.999^{**}$ for EC, $r = 0.753^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available K_2O was seen during the both the years of experiments ($r = -0.681^{**}$ for sand, $r = -0.835^{**}$ for infiltration rate, $r = -0.884^{**}$ for OC in 2012, and $r = 0.666^{**}$ for sand, $r = -0.824^{**}$ for infiltration rate, $r = -0.874^{**}$ for OC in 2013). The available K_2O was non-significantly and positively correlated with silt in both the years of experiment.

At 60DAT, a significant relationship of available K_2O with all physico-chemical properties except silt was seen during both the years of experiment. A highly significant and positive relationship of clay, pH, electrical conductivity and CEC with available K_2O was observed ($r = 0.913^{**}$ for clay, $r = 0.681^{**}$ for pH, $r = 0.999^{**}$ for EC, $r = 0.766^{**}$ for CEC in 2012 and $r = 0.913^{**}$ for clay, $r = 0.681^{**}$ for pH, $r = 0.999^{**}$ for EC, $r = 0.766^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available K_2O was seen during the both the years of experiments ($r = -0.681^{**}$ for sand, $r = -0.835^{**}$ for infiltration rate, $r = -0.884^{**}$ for OC in 2012, $r = -0.681^{**}$ for sand, $r = -0.835^{**}$ for infiltration rate, $r = -0.884^{**}$ for OC in 2013). The available K_2O was non-significantly and positively correlated with silt both the year of experiments.

At 90DAT, a significant relationship of available K_2O with all physico-chemical properties except silt was seen during both the years of experiment. A highly significant and positive relationship of clay, pH, electrical conductivity and CEC with available K_2O was observed ($r = 0.915^{**}$ for clay, $r = 0.684^{**}$ for

pH, $r = 0.999^{**}$ for EC, $r = 0.769^{**}$ for CEC in the 2012 and $r = 0.906^{**}$ for clay, $r = 0.668^{**}$ for pH, $r = 0.999^{**}$ for EC, $r = 0.755^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available K_2O was seen ($r = -0.684^{**}$ for sand, $r = -0.838^{**}$ for infiltration rate, $r = -0.886^{**}$ for OC in 2012 and $r = -0.668^{**}$ for sand, $r = -0.826^{**}$ for infiltration rate, $r = -0.876^{**}$ for OC in 2013). The available K_2O was non-significantly and positively correlated with silt both the year of experiments.

At harvest, a significant relationship of available K_2O with all physico-chemical properties except silt was seen during both the years of experiment. A highly significant and positive relationship of clay, pH, electrical conductivity and CEC with available K_2O was observed ($r = 0.911^{**}$ for clay, $r = 0.677^{**}$ for pH, $r = 0.999^{**}$ for EC, $r = 0.762^{**}$ for CEC in 2012 and $r = 0.905^{**}$ for clay, $r = 0.667^{**}$ for pH, $r = 0.999^{**}$ for EC, $r = 0.753^{**}$ for CEC in 2013). A highly significant and negative relationship of sand, infiltration rate and OC with available K_2O was seen ($r = -0.676^{**}$ for sand, $r = -0.832^{**}$ for infiltration rate, $r = -0.881^{**}$ for OC in 2012, $r = -0.666^{**}$ for sand, $r = -0.824^{**}$ for infiltration rate, $r = -0.875^{**}$ for OC in 2013). The available K_2O was non-significantly and positively correlated with silt both the year of experiments.

In the present study soil characteristics' (pH and clay) were found to be positively and significantly correlated with available K_2O of soil indicating that the increase in content of available K with increase in content of pH and clay. Alexander (1991) and Mali (1989) also showed that the soil characteristics' (pH and clay) were found to be positively correlated with available K_2O of soil. In the present study soil organic carbon was found to be negatively correlated with soil potassium in the soil. Alexander (1991) was also showed that the organic carbon was found to be negatively correlated with soil available K_2O in the soil series of Konkan region. In the present study soil characteristics (pH, soil clay content and organic carbon) correlation ship with available K_2O were also found to be in agreement with the findings of Mali (1989). In the present study sand correlated negatively with available K_2O . Kadrekar and Kibe (1972) and Das *et al.*, (2000) also reported that sand percent was negatively correlated with exchangeable K_2O . The cation exchange capacity had positive and significant relationship with available K in both the years in the present study. Similar results were quoted by Das *et al.*, (2000). The organic carbon had negative and significant relationship with available K in both the year similar results were quoted by Das *et al* (2000).

4.8.4 Correlation between various physico-chemical properties with pesticides residues in soil under rice crop

In order to understand the relation between various physico-chemical properties with pesticide residues at different growth stages (30, 60, 90 DAT and at harvest stage) of rice, the correlation coefficient were worked out. The data regarding to the correlation is presented in Table 40 and 41 for first and second year of the experiment respectively and discussed below.

At 30DAT, a non-significant relationship of pesticides residue with all physico-chemical properties was seen during both the years of experiment. The pesticides residue was positively correlated with sand, silt, infiltration rate, organic carbon and was negatively correlated with clay, pH, CEC and EC.

At 60 DAT, a highly significant and negative relationship of pesticides residue with clay and EC was seen during both the years of experiment ($r = -0.532^{**}$ for clay, $r = -0.78^{**}$ for EC in the 2012 and $r = -0.69^{**}$ for EC, $r = -0.463^{**}$ for clay in 2013). The pesticides residue was positively and significantly correlated with organic carbon ($r = 0.481^*$ in 2012 and $r = 0.417^*$ in 2013). Infiltration rate of soil ($r = 0.408^*$) and positively correlated with pesticides residue during the first year of experiment, whereas seen non-significant in the second year of experiment. A non-significant relationship of the pesticides residue with sand, silt, pH and CEC was seen during both the years of experiment.

At 90DAT, a highly significant and negative relationship of pesticide residue with EC was seen during both the years of experiment ($r = 0.726^{**}$ in 2012 and $r = 0.635^{**}$ in 2013). The pesticides residue was positively and significantly correlated with organic carbon ($r = 0.471^*$ in 2012 and $r = 0.417^*$ in 2013). A significant and negative relationship of pesticides residue with clay was seen during both the year of experiment ($r = -0.515^*$ in 2012 and $r = -0.452^*$ in 2013). Infiltration rate of soil was seen significant ($r = 0.407^*$) and positively correlated with pesticides residue during the first year of experiment whereas seen non-significant in the second year of experiment. A non-significant relationship of pesticides residue with sand, silt, pH and CEC was seen during both the years of experiment.

At harvest, a highly significant and negative relationship of pesticides residue with EC was seen during both the years of experiment ($r = -0.751^{**}$ in 2012 and $r = -0.708^{**}$ in 2013). A significant and negative relationship of pesticides residue with clay was seen during the first year of experiment ($r = -0.484^*$) in the first year and was found non-significant in the second year of experiment. A non-significant relationship of pesticides residue with sand, silt, infiltration rate pH and CEC was seen during both the years of experiment. Organic Carbon of soil was seen significant ($r = 0.432^*$) and positively correlated with pesticides residue during the first year of experiment whereas seen non-significant in the second year of experiment.

The significant positive correlation between the organic carbon and pesticides residues was recorded in the present study. Similar results were quoted by Parama (1991), and Baskaran *et al.*, (2010). The non significant relation of pH and pesticides residue was found in both the years of experiment. A non significant relationship was observed between sand, silt and pesticides residues in soil.

B. Experiment-II

4.9 Effect of soil types on pesticides leaching losses and their movement in soil profile at different depth.

4.9.1 Leaching losses of pesticides from different soil matrices (column) as affected by various treatments.

The data regarding the leaching losses of the pesticides from soil matrices at 30, 60 and 90 DAA (Day after application) as influenced by various treatments is given in Table 42 (Fig 40) Periodic release of pesticides in leachates from the different soil depths is shown in Figure 41 and 42.

The leaching losses of the pesticides in the percolates from soil column at various DAA (30, 60 and 90 DAA (Day after application) to soil were analyzed for both the pesticides viz., PI (Carbofuron) and PII (Phorate).

The data presented in Table 42 reveals that the leaching losses of pesticides from soil columns observed to vary from 84.7 to 724.9 $\mu\text{g column}^{-1}$, 61.0 to 821.0 $\mu\text{g column}^{-1}$ among the different treatments in first and second year of experiment, respectively. It is observed from the data that the leaching losses of pesticides under various treatments were significantly influenced.

Table 42: Leaching losses of different pesticides from different types of soil column.

Treatments	$\mu\text{g per column (2012)}$		$\mu\text{g per column (2013)}$	
	PI	PII	PI	PII
T ₁ -30DAA	409	185.9	460	210
T ₂ -60DAA	724.2	331.4	821	368
T3-90DAA	724.9	331.7	821	368
T4-30DAA	276.0	94.5	304	102
T5-60DAA	452.4	167.4	501	188
T6-90DAA	452.9	167.4	500	188
T7-30DAA	149.1	53.06	156	61

T8-60DAA	255.4	84.0	282	98
T9-90DAA	255.1	84.7	282	97
	SEm $\pm$	C.D.	SEm $\pm$	C.D.
soil type	8.08	31.1	9.96	38.32
soilXpest	11.4	43.99	14.09	54.20

Leaching losses of pesticides from soil columns having Lateritic soil, varied from 185.9 to 409.0 $\mu\text{g column}^{-1}$, 331.4 to 724.2 $\mu\text{g column}^{-1}$ and 331.7 to 724.9 $\mu\text{g column}^{-1}$ at 30DAA, 60 DAA and 90 DAA respectively during first year of experiment while in second year of experiment, its content varied from 210.0 to 460.0 $\mu\text{g column}^{-1}$, 368.0 to 821.0 $\mu\text{g column}^{-1}$ and 368.0 to 821.0 $\mu\text{g column}^{-1}$ at 30, 60 and 90DAA respectively. Leaching losses of pesticides from Medium black soil treated columns varied from 94.5 to 276.06 $\mu\text{g column}^{-1}$, 167.46 to 452.4 $\mu\text{g column}^{-1}$ and 167.4 to 452.9 $\mu\text{g column}^{-1}$ from 30, 60 and 90DAA respectively, during first year of experiment while in second year of experiment, its content varied from 102 to 304 $\mu\text{g column}^{-1}$, 188 to 501 $\mu\text{g column}^{-1}$ and 188 to 500 $\mu\text{g column}^{-1}$ from 30, 60 and 90DAA respectively. In Coastal saline soil, leaching losses of pesticides content varied from 53.06 to 149.1 $\mu\text{g column}^{-1}$, 84.0 to 255.43 $\mu\text{g column}^{-1}$ and 84.7 to 255.1 $\mu\text{g column}^{-1}$ in 30, 60 and 90 DAA respectively during first year of experiment while in second year of experiment, its content varied from 61.0 to 156.0 $\mu\text{g column}^{-1}$, 98.0 to 282.0 $\mu\text{g column}^{-1}$ and 97.0 to 282.0 $\mu\text{g column}^{-1}$ in 30, 60 and 90 DAA respectively. The leaching losses of pesticides were found to be significantly higher (724.9 and 821 $\mu\text{g column}^{-1}$ in first and second year of experiment, respectively) in (Lateritic soil + Carbofuron + 90 DAA).

The column which was kept for 90DAA (days after application) of pesticides showed maximum value of pesticides in percolates which was similar to column kept for 60 days (60 DAA). Irrespective of the soil types it is observed that the pesticides residues content at 60 DAA and 90 DAA is nearly constant. This is due to the fact that the leachate was collected at an interval of seven days pooled and analyzed for pesticides content. In both the pesticides under study the pooled leachate of 42-49 days interval was detected but in the leachate at 50-56 days no pesticides residue was detected. The maximum amount of pesticide was seen in the column 90DAA which was almost similar with 60DAA column in all the soil types.

The maximum leaching loss of pesticides was observed in Lateritic soils (7.41 to 11.14 percent of applied quantity) followed by Medium black soil (3.75 to 6.78 percent) and least in Coastal saline soil (1.88 to 3.82 percent) when the columns were kept for 90 days. Similar results were quoted by Redder *et al.*, (1989 and 1991). They reported that Lateritic soil column being a light textured soil with low CEC and higher infiltration rate favoured easy downward movement of applied pesticides as compared to Medium black and Coastal saline soil columns which have high CEC in Vertisol (Medium black and Coastal saline soil) possibly caused greater retention of pesticides. The maximum leaching loss of pesticides in Lateritic soil may be due to low CEC. The leaching loss of pesticides were recorded less in Medium black and Coastal saline columns dominated by 2:1 type smectite clay minerals and red Lateritic soil dominated by Kaolinite type 1:1 type mineral. (Yaron 1978). High adsorption may reduce the mobility and leaching potential of pesticides through the soil column. It could therefore, be concluded that, clay content in the soil may increase adsorption, consequently reducing the leaching of pesticides as shown from the results of the present study.

The lowest value of pesticides in percolates of Coastal saline soil columns may be due to saline nature of the soils. Battala *et al.*, (2012) observed that the rate of degradation of pesticides was faster by increase in soil salinity. The rate of degradation of pesticides to other form is quite faster in salt affected saline soil than non saline soil.

Among the pesticides (PI) and (PII) treatments under study, the Carbofuron (PI) recorded the higher (3.46 to 11.14 percent) leaching losses at all the sampling period over Phorate (PII) (1.88 to 8.24 percent).

Among the pesticides (PI) Carbofuron and (PII) Phorate under study treatments Carbofuron (PI) recorded the higher leaching losses at all the sampling period which were significantly superior over Phorate treated soil columns irrespective of soil type. This might be due to the fact that Phorate has lower solubility (22 mg litre^{-1}) as compared to Carbofuron (350mg litre^{-1}).

4.9.2 Effect of different treatment on persistence of pesticides at different depth of soil column.

The data pertaining to the downward movement behavior of pesticides (PI and PII) in different soil types was studied using soil columns. The mobility of applied pesticide residues in various soil types using soil columns at different depth of soil profiles viz. 0-30, 30-60, 60-90 cm as sampled after 30, 60 and 90DAA are presented in Table 43 and 44(Fig 43 and 44).

Table 43: Effect of different treatment on persistence of pesticides at different depth of soil column. (2012)

Pesticides residues $\mu\text{g kg}^{-1}$ (2012)						
Treatment	0-30cm		30-60cm		60-90cm	
	PI	PII	PI	PII	PI	PII
T1-30DAA	1193	687	40	32	10	2
T2-60DAA	521	197	55	39	62	38
T3-90DAA	92	58	83	42	111	51
T4-30DAA	1414	816	25	21	6	3
T5-60DAA	669	286	51	31	43	33
T6-90DAA	96	75	71	36	82	40

T7-30DAA	1010	553	18	12	5	0.9
T8-60DAA	462	152	31	20	6	2
T9-90DAA	81	44	58	23	9	4
	SEm $\pm$	C.D.	SEm $\pm$	C.D.	SEm $\pm$	C.D.
soil type	11.59	44.5	1.79	6.88	4.09	15.76
soilXpest	16.39	63.0	2.53	9.73	5.79	22.29

Carbofuron (PI) and Phorate (PII)

Table 44: Effect of different treatment on persistence of pesticides at different depth of soil column. (2013)

Pesticides residues $\mu\text{g kg}^{-1}$ (2013)						
Treatment	0-30cm		30-60cm		60-90cm	
	PI	PII	PI	PII	PI	PII
T1-30DAA	1282	732	51	31	13	5
T2-60DAA	563	153	65	41	73	32
T3-90DAA	81	62	75	36	102	48
T4-30DAA	1561	891	30	23	8	2
T5-60DAA	588	233	58	34	56	22
T6-90DAA	95	66	67	30	88	44

T7-30DAA	979	550	13	10	3	1.2
T8-60DAA	367	98	26	21	9	2
T9-90DAA	73	40	48	28	12	4
	SEm $\pm$	C.D.	SEm $\pm$	C.D.	SEm $\pm$	C.D.
soil type	20.47	78.74	1.39	5.35	3.13	12.0
soilXpest	28.95	111.3	1.96	7.56	4.43	17.0

Carbofuron (PI) and Phorate (PII)

In different soil type under study the Carbofuron (PI) content at various depths were analysed during 2012 and 2013. The range of Carbofuron (PI) residue in soil column in 2012 at depth 0-30cm was observed to be 81.0 to 1414.0 $\mu\text{g kg}^{-1}$, at 30-60cm it was 18 to 83.0 $\mu\text{g kg}^{-1}$, and 60-90cms was in the range of 5.0 to 111.0 $\mu\text{g kg}^{-1}$, respectively. And in the year 2013 the values were in the range of 73.0 to 1561.0 $\mu\text{g kg}^{-1}$, 13.0 to 75.0 $\mu\text{g kg}^{-1}$ and 3.0 to 102.0 $\mu\text{g kg}^{-1}$ at 0-30cm, 30-60cm, and 60-90cm depth respectively.

The depthwise Phorate (PII) residue in soil column at different soil type in 2012 at depth 0-30cm, 30-60cm, and 60-90cms was in the range of 44.0 to 816.0 $\mu\text{g kg}^{-1}$, 12.0 to 42.0 $\mu\text{g kg}^{-1}$ and 0.9 to 51.0 $\mu\text{g kg}^{-1}$ respectively. The values were in the range of 40.0 to 891.0 $\mu\text{g kg}^{-1}$, 10.0 to 41.0 $\mu\text{g kg}^{-1}$ and 1.2 to 48.0 $\mu\text{g kg}^{-1}$ at 0-30 cm, 30-60 cm, and 60-90 cm depth respectively during the year 2013.

At the depth of 0-30cm the soil analysis in the year 2012 reveals that irrespective of soil type the Carbofuron (PI) residues content was maximum at 30DAA thereafter it gradually decreased upto 90 DAA. The maximum content was observed in Medium black soil (1414.0 $\mu\text{g kg}^{-1}$) followed by Lateritic soil (1193.0 $\mu\text{g kg}^{-1}$) and the low (1010.0 $\mu\text{g kg}^{-1}$) in Coastal saline soil. In the year 2013 similar trend of decrease in the Carbofuron (PI) content was

observed from 30 DAA to 90DAA. The maximum Carbofuron (PI) content 30cm was observed in Medium black soil ($1561.0 \mu\text{g kg}^{-1}$) followed by Lateritic soil ($1282.0 \mu\text{g kg}^{-1}$) and the low ($979.0 \mu\text{g kg}^{-1}$) in Coastal saline soil in the year (2013).

At the depth of 0-30cm, the soil analysis in the year 2012 reveals that irrespective of soil type the Phorate (PII) residues content was maximum at 30DAA thereafter it gradually decreased upto 90 DAA. The maximum content was observed in Medium black soil ($816.0 \mu\text{g kg}^{-1}$) followed by Lateritic soil ($687.0 \mu\text{g kg}^{-1}$) and the low ($553.0 \mu\text{g kg}^{-1}$) in Coastal saline soil. In the year 2013 similar trend of decrease in the Phorate (PII) content was observed from 30 DAA to 90DAA. The maximum Phorate (PII) content was observed in Medium black soil ($891.0 \mu\text{g kg}^{-1}$) followed by Lateritic soil ($732.0 \mu\text{g kg}^{-1}$) and the low ($550.0 \mu\text{g kg}^{-1}$) in Coastal saline soil in the year (2013).

At the depth of 30-60cm the soil analysis in the year 2012 reveals that irrespective of soil type the Carbofuron (PI) residues content was minimum at 30DAA thereafter it gradually increased upto 90 DAA. The maximum content was observed in Lateritic soil ($83.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($71.0 \mu\text{g kg}^{-1}$) and the low ($58.0 \mu\text{g kg}^{-1}$) in Coastal saline soil. In the year 2013 similar trend of increase in the Carbofuron (PI) content was observed from 30 DAA to 90DAA. The maximum Carbofuron (PI) content was observed in Lateritic soil ($75.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($67.0 \mu\text{g kg}^{-1}$) and the low ($48.0 \mu\text{g kg}^{-1}$) in Coastal saline soil in the year (2013).

At the depth of 30-60cm the soil analysis in the year 2012 reveals that irrespective of soil type the Phorate (PII) residues content was minimum at 30DAA thereafter it gradually increased upto 90 DAA. The maximum content was observed in Lateritic soil ($42.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($36.0 \mu\text{g kg}^{-1}$) and the low ($23.0 \mu\text{g kg}^{-1}$) in Coastal saline soil. In the year 2013 similar trend of increase in the Phorate (PII) content was observed from 30 DAA to 90DAA. The maximum Phorate (PII) content was observed in Lateritic soil ($36.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($30.0 \mu\text{g kg}^{-1}$) and the low ($28.0 \mu\text{g kg}^{-1}$) in Coastal saline soil in the year (2013).

At the depth of 60-90cm the soil analysis in the year 2012 reveals that irrespective of soil type the Carbofuron (PI) residues content was minimum at 30DAA thereafter it gradually increased upto 90 DAA. The maximum content was observed in Lateritic soil ($111.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($82.0 \mu\text{g kg}^{-1}$) and the low ($9.0 \mu\text{g kg}^{-1}$) in Coastal saline soil. In the year 2013 similar trend of increase in the Carbofuron (PI) content was observed from 30 DAA to 90DAA. The maximum Carbofuron (PI) content was observed in Lateritic soil ($102.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($88.0 \mu\text{g kg}^{-1}$) and the low ($12.0 \mu\text{g kg}^{-1}$) in Coastal saline soil in the year (2013).

At the depth of 60-90cm the soil analysis in the year 2012 revealed that irrespective of soil type the Phorate (PII) residues content was minimum at 30DAA thereafter it gradually increased upto 90 DAA. The maximum content was observed in Lateritic soil ($51.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($40.0 \mu\text{g kg}^{-1}$) and the low ($4.0 \mu\text{g kg}^{-1}$) in Coastal saline soil. In the year 2013 similar trend of increase in the Phorate (PII) content was observed from 30 DAA to 90DAA. The maximum Phorate (PII) content was observed in Lateritic soil ($48.0 \mu\text{g kg}^{-1}$) followed by Medium black soil ($44.0 \mu\text{g kg}^{-1}$) and the low ($4.0 \mu\text{g kg}^{-1}$) in Coastal saline soil in the year (2013).

The depthwise data of pesticides residues analysis of soil column indicates that that higher residue irrespective of soil type is observed at 0-30cm than compared to 30-60cm and 60-90 cm depth of soil column in both the year of the experiment. Pesticide sorption was greater in surface horizons than in subsoil. Baskaran *et al.*, (2010). It was also observed that the residue of pesticides decreased with increasing depth of the soils. More residues were accumulated at the top layers of the soil column.

Among the different soil types, the pesticides residues content was maximum in Medium black soil followed by Lateritic soil and Coastal saline soil at 0-30cm depth. However as the depth increased from 30-60cm and 60-90cm the Lateritic soil showed maximum residues content followed by Medium black soil. Coastal saline soil has minimum pesticides content as compared to other two soil types.

At depth of 30-60cm and 60-90cm Lateritic soils have shown the maximum pesticides residues than compared to other two soil types. This may be due to higher adsorption and less leaching capacity of the Medium black soil. The higher pesticides residues adsorption in smectitic rich soil was also recorded by Yaron (1978). He further concluded that residues content of pesticides increased with increasing swelling capacity of clay because of swelling type clay. Pesticides residues get absorbed in Smectite (2:1) type of clay structure in higher amount whereas the pesticides residues get adsorbed on the Kaolinite type in lower amount. Keiger and Yaron (1975) concluded that soils which contain Smectite clay retain pesticides much more strongly than kaolinitic clays.

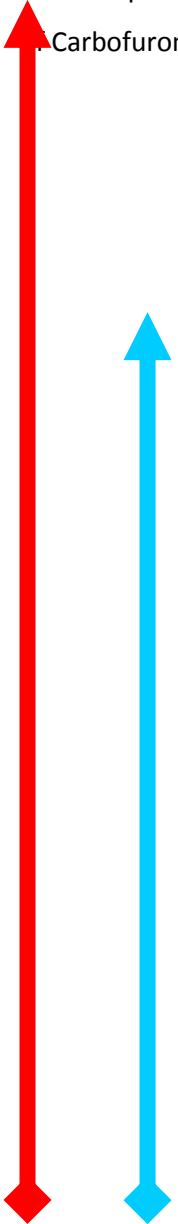
The higher pesticides residues at these two depths (30-60cm and 60-90cm) in Lateritic soil column might be due to accumulation of leached pesticides in the lower layer from upper layer of soil. The higher leaching rates of pesticides in Lateritic soil column and their accumulation in lower depth as compared to Medium black and Coastal saline soil was also reported by Reddar *et al.*, (1989).

The pesticides residues content in soil column at 0-30 cm, a linear decrease is seen due to the fact that the soil applied insecticides are undergoes to through important processes like adsorption, degradation and leaching losses with water, supporting their loss at different depths. The results in the present investigation were in agreement with Das and Mukherjee (1998b), Das and Mukherjee (1994) and Das *et al.*, (2003).

The data on pesticides residues at 30-60cm, 60-90cm depths reveals that as the number of days increased there was a gradual increase in the pesticide residues at all the soils under study in both the year of experiments. The increase in pesticides residues content was due to mobilization of pesticides residues with percolating water from upper layer to lower layer. Pesticides movement along with percolating water from upper layer to lower layer of soil increased the pesticides residue accumulation at lower depths of soil.

As per the soil pesticides residues and movements of pesticides (PI and PII) in concern to the results revealed that soil column, the Carbofuron (PI) moves faster from upper layer to lower layer as compared to Phorate (PII) irrespective of soil type and the depth of soil column. This can be attributed due

to low degradation rate and high solubility of Carbofuron of ($350 \text{ mg liter}^{-1}$) as compared to Phorate (22 mg liter^{-1}). Bhuvaneswari *et al.*, (2011) has reported that comparative degradation of Phorate and Carbofuron, Phorate is degraded at a faster rate which renders it unavailable for movement and the solubility of Carbofuron which is higher than the Phorate helps in its faster downward movement through percolating water.





INTRODUCTION



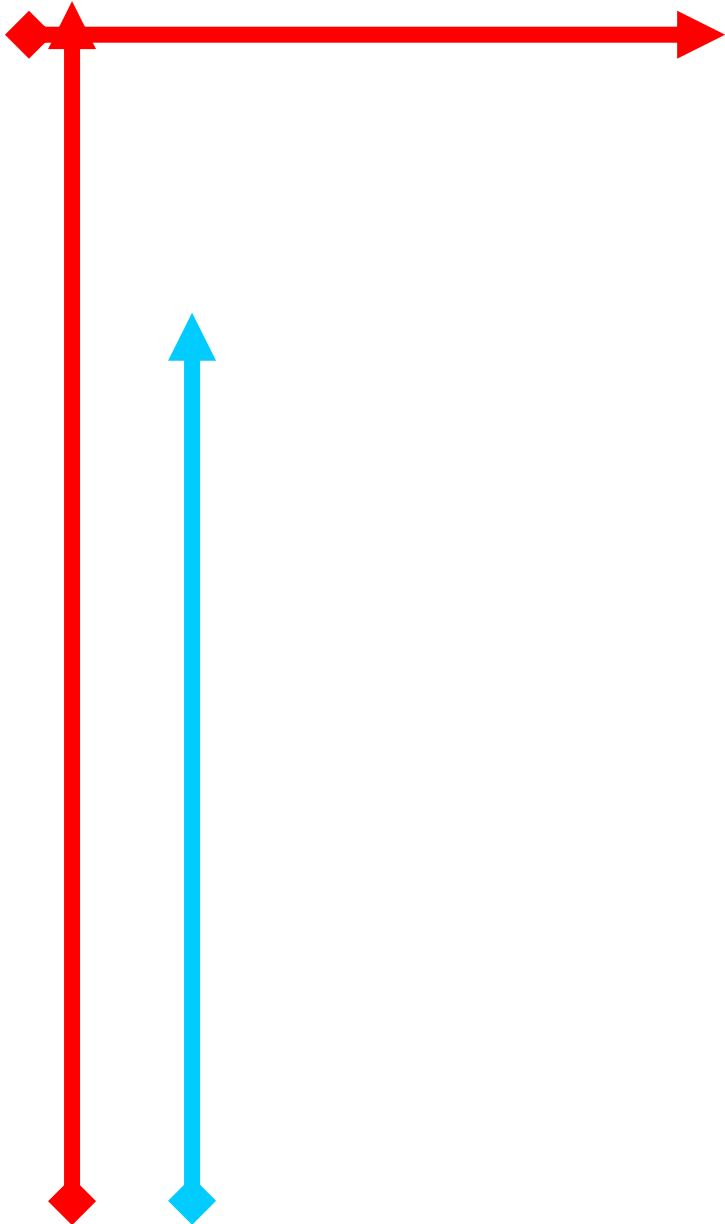


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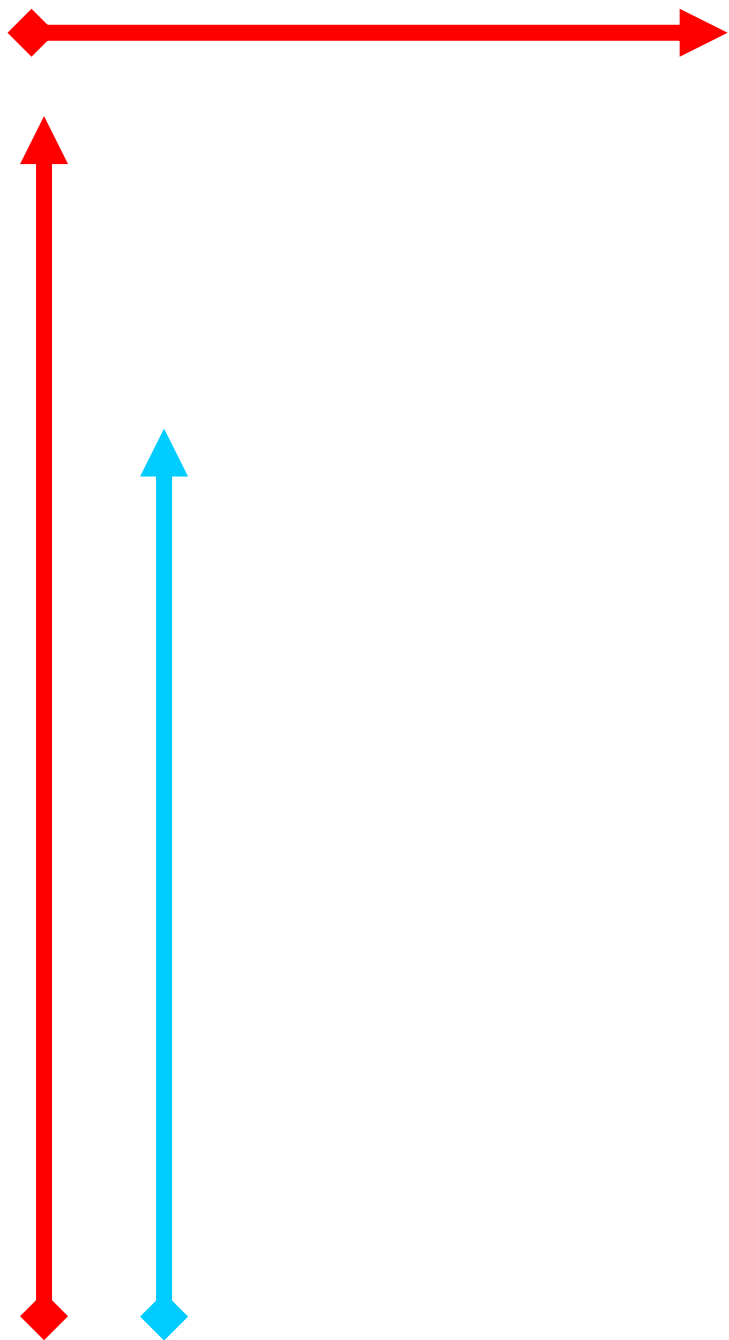






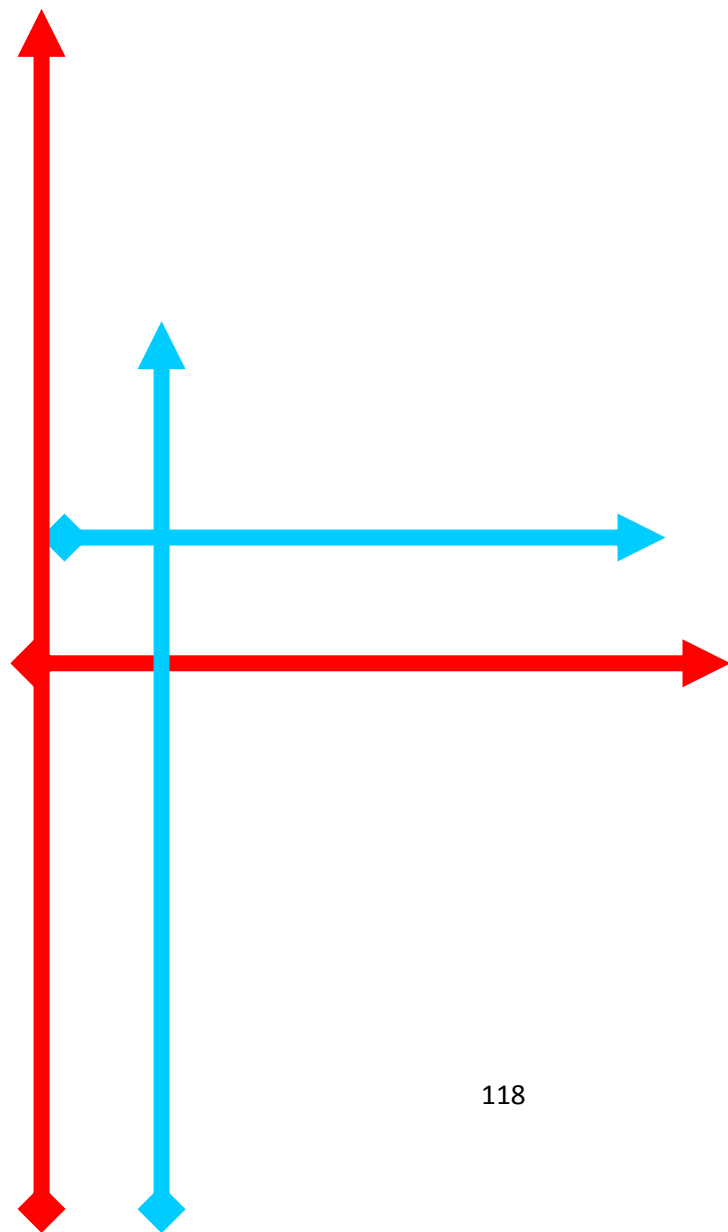
MATERIAL AND METHODS







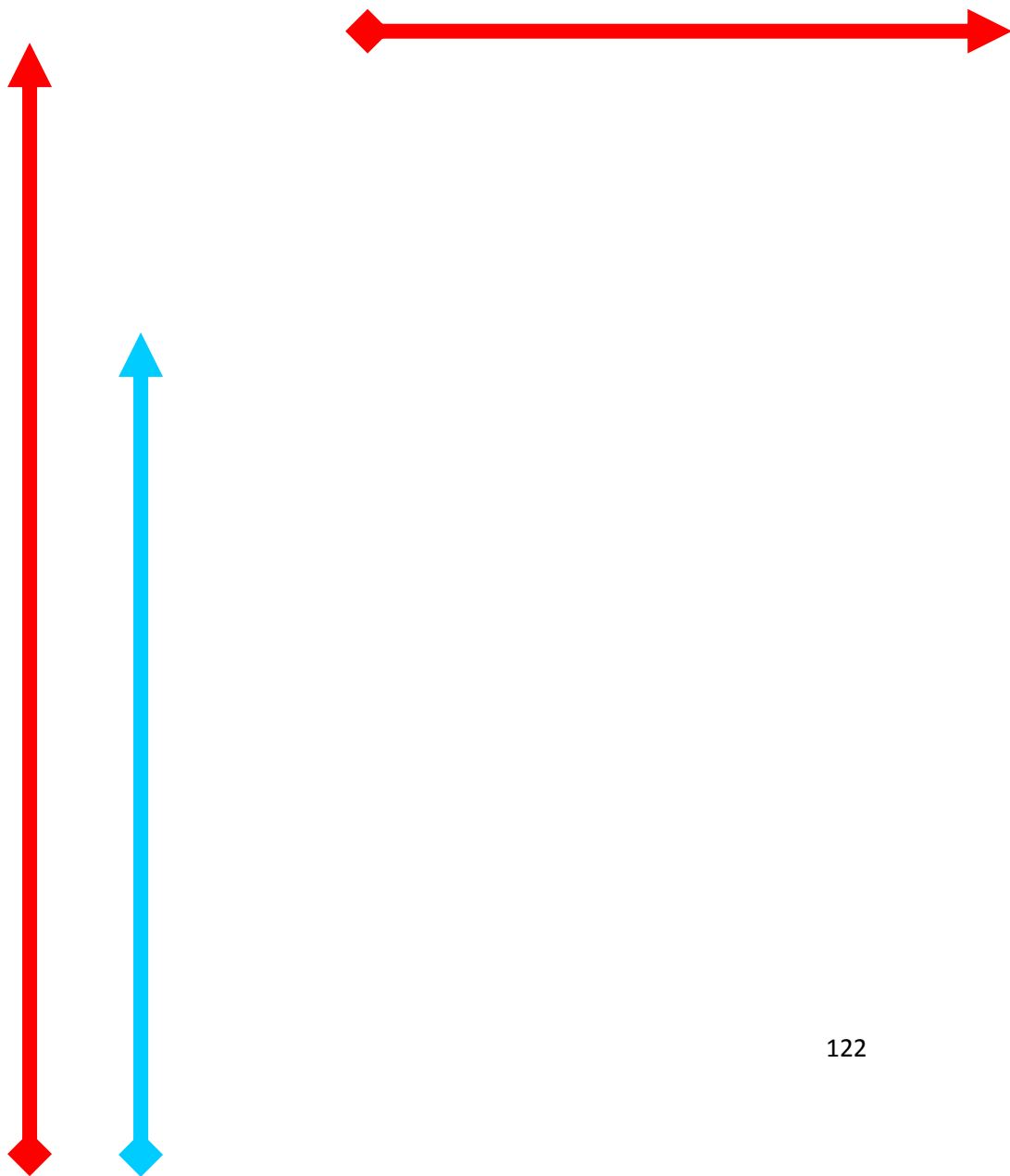
RESULTS AND DISCUSSION





SUMMARY AND CONCLUSION

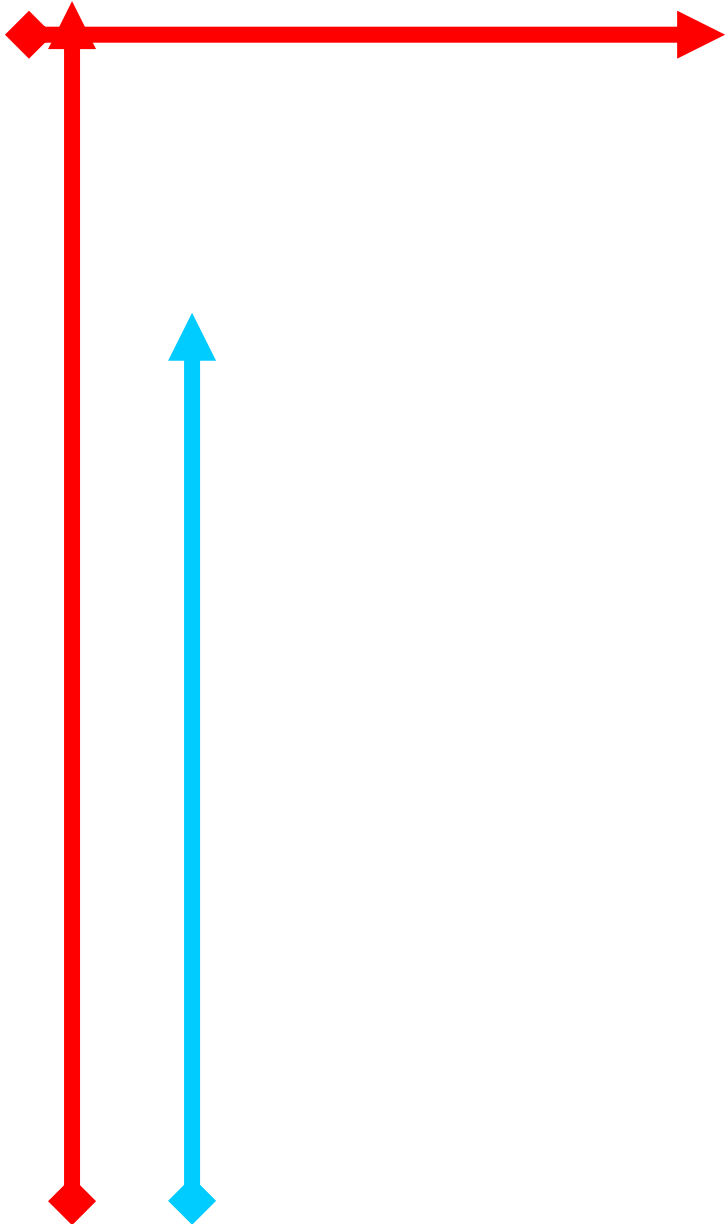






LITERATURE CITED







LITERATURE CITED





CHAPTER V

SUMMARY AND CONCLUSIONS

The present investigation pertaining to the studies on the “movement behaviour of primary nutrients, carbamate and organophosphate based insecticides in different soil matrices” was conducted during *Kharif*, 2012 and 2013. The analytical work was done in the research laboratory of Department of Soil Science and Agricultural Chemistry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri and in NEERI Nagpur. In order to represent these three distinct soil types of Konkan, three representative soil profiles samples, one each from Lateritic, Medium black and Coastal saline soil were used. In the present investigation with surface soil samples, subjected to study leaching losses of NPK and pesticides from rice growing pots (Experiment-I) while the other set of experiment with soil samples at various depths was subjected to leaching losses of pesticides and to study their movement and distribution using soil column. (Experiment-II)

The effect of different treatments on content, uptake of primary nutrients by rice crop in different soil types and the changes in primary nutrient availability under rice crop as affected by pesticides application and its leaching losses was studied. Movement and distribution of pesticides in profile of different soil types using soil column were carried out. The residues content of different pesticides in rice grain, straw and soil was analyzed. The important findings evolved from the present investigation are summarized below:

A Experiment-I

5.1 Leaching losses of primary nutrients and pesticides at different growth stages of rice crop as affected by various treatments.

5.1.1 Leaching losses of Nitrogen:

The leaching losses of the nitrogen from soil under rice crop in the percolates were analyzed in both the form viz., ammonical- N, and nitrate - N.

5.1.1.1 Ammonical-N (NH_4^+ -N):

The leaching losses of ammonical-N from soil among the different treatments were observed to be varied from 9.49 to 39.22 mgpot⁻¹, 9.00 to 31.73 mgpot⁻¹ and 5.39 to 29.31 mgpot⁻¹ at 30, 60 and 90DAT respectively in 2012. In 2013, the leaching losses of ammonical-N from soil among the different treatments were observed to be varied from 11.05 to 38.9 mgpot⁻¹, 7.93 to 28.62 mgpot⁻¹ and 7.05 to 25.94 mgpot⁻¹ among the different treatments of rice at 30, 60 and 90DAT respectively. The leaching losses of ammonical-N was found to be significantly superior in T₃ (Lateritic soil + RDF + Phorate) treatment at each sampling period in the both years of experiment.

The total (0-90 DAT) leaching loss of ammonical-N was observed maximum (13.37 to 15.08 percent of applied quantity) from the Lateritic soil followed by Medium black soil (9.5 to 11.37 percent) and was minimum in Coastal saline soil (3.59 to 4.21 percent).

5.1.1.2 Nitrate-N (NO_3^- -N):

The leaching losses of nitrate-N from soil were observed to be varied from 7.95 to 20.14 mg pot⁻¹, 5.71 to 15.37 mg pot⁻¹ and 3.33 to 12.53 mg pot⁻¹ among the different treatments of rice at 30, 60 and 90 DAT respectively in 2012. However in 2013 its content was observed to be varied from 7.44 to 19.33 mg pot⁻¹, 5.69 to 14.63 mg pot⁻¹ and 3.50 to 11.47 mg pot⁻¹ among the different treatments of rice at 30, 60 and 90 DAT respectively. The leaching losses of nitrate-N was found to be significantly superior in T₃ (Lateritic soil + RDF + Phorate) treatment at all the sampling periods in the both year of experiment.

The total loss of nitrate-N over 90 days was observed to be maximum in (6.63 to 7.23 percent of applied quantity) the Lateritic soil followed by Medium black soil (3.85 to 4.79 percent) and was minimum in Coastal saline soil (2.50 to 2.74 percent).

5.1.1.3 Total N (Ammonical-N + Nitrate-N) leaching losses:

The leaching losses total N (ammonical-N + nitrate-N) from soil were observed to be varied from 17.44 to 59.35 mg pot⁻¹, 14.71 to 47.10 mg pot⁻¹ and 8.72 to 41.84 mg pot⁻¹ among the different treatments of rice at 30, 60 and 90 DAT respectively in 2012. The leaching losses of total N (ammonical-N + nitrate-N) from soil were observed to be varied from 19.29 to 57.72 mg pot⁻¹, 13.62 to 43.25 mg pot⁻¹ and 10.55 to 37.42 mg pot⁻¹ among the different treatments of rice at 30, 60 and 90 DAT respectively in 2013. The leaching losses of total (ammonical-N + nitrate-N) N was found to be highest in T₃ (Lateritic soil + RDF + Phorate) treatment at all the sampling stages in the both years of experiment.

The cumulative total (ammonical-N + nitrate-N) leaching loss over 90 days was observed maximum (20.00 to 22.31 percent of applied quantity) from the Lateritic soil while it was observed minimum in Medium black soil 14.13 to 15.67 percent of applied quantity) followed by

Coastal saline soil (6.15 to 6.84 percent of applied quantity). The maximum leaching loss of total N (ammonical- N+ nitrate -N) occurred at first observation (0-30 DAT) period and afterwards it showed declined trend gradually in subsequent observations and it was recorded minimum in the last observation (at 30-90 DAT) irrespective of soil type. Among the two form of N in leachate, the ammonical-N content in leachate was recorded higher than nitrate-N form at each period of sampling irrespective of soil type.

5.1.2 Leaching losses of phosphorous at different growth stages of rice crop as affected by various treatments.

The leaching losses of phosphorous from soil were observed to be varied from 1664.0 to 4144.0 $\mu\text{g pot}^{-1}$, 1312.0 to 2032.0 $\mu\text{g pot}^{-1}$ and 736.0 to 1136.0 $\mu\text{g pot}^{-1}$ among the different treatments of rice at 30, 60 and 90DAT respectively in 2012. however in 2013 its content were observed to be varied from 1280.0 to 3520.0 $\mu\text{g pot}^{-1}$, 688.0 to 1541.0 $\mu\text{g pot}^{-1}$ and 656.0 to 819.0 $\mu\text{g pot}^{-1}$ among the different treatments of rice at 30, 60 and 90DAT respectively. The leaching losses of phosphorous was found to be significantly superior in T_3 (Lateritic soil + RDF + Phorate) treatment.

The maximum percent leaching loss over 90 days in total was observed maximum (2.58 to 3.28 percent of applied quantity) in Lateritic soil followed by Medium black soil (2.02 to 2.47 percent) while it was minimum (1.18 to 1.74 percent) in Coastal saline soil. The trend in leaching loss of phosphorous showed a linear decrease from 0-30 to 60-90 days irrespective of soil type.

5.1.3 Leaching losses of potassium at different growth stages of rice crop as affected by various treatments.

The leaching losses of potassium from soil were observed to be varied from 18.44 to 66.11 mg pot^{-1} , 13.35 to 48.38 mg pot^{-1} and 7.90 to 25.75 mg pot^{-1} among the different treatments of rice at 30 60 and 90DAT respectively in 2012. however in 2013 its content were observed to be varied from 16.29 to 60.90 mg pot^{-1} , 13.17 to 47.60 mg pot^{-1} and 8.86 to 28.14 mg pot^{-1} among the different treatments of rice at 30 60 and

90DAT respectively . The leaching losses of potassium was found to be significantly superior in T₉ (Coastal saline soil + RDF + Phorate) treatment at each sampling

The leaching loss of potassium when compared to the different soil types reveals that, loss was observed maximum in Coastal saline soils (60.34 to 62.83 percent of applied quantity) followed by Lateritic soil (23.24 to 25.33 percent) and was minimum in Medium black soil (16.79 to 18.62 percent). The maximum leaching loss of potassium occurred at 0-30 DAT period and afterwards it showed declined trend gradually in subsequent observations and it was recorded minimum in the last observation (at 60-90 DAT) irrespective of soil type.

5.1.4 Leaching losses of pesticides at different growth stages of rice crop as affected by various treatments.

The leaching losses of the pesticides from soil under rice crop at different growth stages at weekly interval up to 49 days were analyzed but were below the detection limits after seventh week (43-49 days).

The leaching losses of pesticides from soil were observed to be varied from 313.8 to 3728.8 $\mu\text{g pot}^{-1}$ and 154.7 to 1866.3 $\mu\text{g pot}^{-1}$ at 0-28 DAT and 29-42 DAT among the different treatments of rice in 2012 while in the 2013, its content varied from 477.2 to 2101.8 and 239.4 to 1051.0 $\mu\text{g pot}^{-1}$ at 0-28 DAT and 29-42 DAT respectively. The leaching losses of pesticides were found to be significantly superior in (Lateritic soil + RDF + PII (Carbofuron)) treatment at each sampling period in the both year of experiment. The leaching loss of pesticides was observed maximum in Lateritic soil (4.20 to 7.59 percent of applied quantity) followed by Medium black soil (1.84 to 4.35 percent) and was lowest in Coastal saline soil (0.63 to 1.84 percent). Among the two pesticides when compared, the leaching losses were higher in Carbofuron treatments (1.84 to 7.59 percent) than Phorate (0.63 to 5.91 percent) irrespective of soil type.

The overall data regarding to the leaching losses of the N, P and pesticides from soil under rice crop was observed to be maximum in Lateritic soil followed by Medium black soil and was minimum in Coastal saline soil.

5.2 Effect of different treatments on growth and yield of rice.

5.2.1 Effect of different treatments on growth of rice.

The growth parameters viz plant height, number of leaves, number of tillers of rice was found to be maximum in T₆ (Medium black soil + RDF + Phorate) treatment. Among the various soil types, the Medium black soil was most suitable which was followed by Lateritic soil and Coastal saline soil. Application of pesticides (Carbofuron and Phorate) showed positive effect on growth parameters viz plant height, number of leaves, and number of tillers as compared to pesticide untreated irrespective of soil type.

5.2.2 Grain yield (g pot⁻¹)

The grain yield of rice was observed to vary from 9.78 to 19.86 g pot⁻¹ and 9.26 to 18.66 g pot⁻¹ among the different treatments of rice in 2012 and 2013 respectively. The grain yield of rice was found to be significantly superior (19.8 g pot⁻¹ in 2012 and 18.6 g pot⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment in both the year of experiment. Application of pesticides (Carbofuron and Phorate) increased the grain yield of rice in the soil as compared to pesticide untreated soil. The treatments receiving Phorate recorded the highest grain yield of rice which was higher over Carbofuron in all soil types. The highest grain yield was recorded (17.8 to 19.8 g pot⁻¹) in Medium black followed by Lateritic soil (13.2 to 15.12 g pot⁻¹) and was lowest in Coastal saline soil (9.2 to 10.5 g pot⁻¹).

5.2.4.2. Straw yield (g pot⁻¹)

The straw yield of rice was observed to be varied from 12.5 to 25.06 g pot⁻¹ and 12.79 to 25.63 g pot⁻¹ among the different treatments of rice at harvest in 2012 and 2013 respectively. The straw yield of rice was found to be significantly superior (25.0 g pot⁻¹ in 2012 and 25.6 g pot⁻¹ in 2013) in T₆ (Medium black soil + RDF + Phorate) treatment in the both year of experiments. Application of pesticides (Carbofuron and Phorate) increased the straw yield of rice in the soil as compared to pesticide untreated soil. The treatments receiving Phorate recorded the highest the straw yield of rice which were higher over Carbofuron in all soil types. The data indicated that, among the various soil types, the straw yield of rice was observed to be maximum in Medium black (21.1 to 25.6 g pot⁻¹) followed by Lateritic soil (15.3 to 18.1 g pot⁻¹) and was lowest in Coastal saline soil (12.5 to 13.5 g pot⁻¹).

5.2.4.3 Total biomass yield of rice (g pot⁻¹):

The total biomass yield of rice were observed from 22.8 to 44.93 g pot⁻¹ and 22.06 to 44.3 g pot⁻¹ among the different treatments of rice in the year 2012 and 2013 experiment respectively. The total biomass yield of rice was found to be significantly superior (44.9 and 44.3 g pot⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment in the both the years of experiment. Application of pesticides (Carbofuron and Phorate) increased the total biomass yield of rice in the soil as compared to pesticide untreated soil. Among the pesticides, the treatments receiving Phorate recorded the highest total biomass yield of rice which was higher over Carbofuron. Among the various soil types, the total biomass yield of rice was maximum in Medium black (39.9 to 44.9 g pot⁻¹) followed by Lateritic soil (28.3 to 33.5 g pot⁻¹) and was lowest in Coastal saline soil (22.0 to 23.75 g pot⁻¹).

The growth parameters viz., plant height, number of leaves, number of tillers, grain yield, straw yield and total biomass yield of rice found maximum in Medium black soil followed by Lateritic soil and was lowest in Coastal saline soil. Application of pesticides (Carbofuron and

Phorate) along with fertilizers at their recommended dose to rice crop increased the yield of rice irrespective of soil type. The stimulating effect of phorate in contributing all of the growth parameters and yield of rice was found more over Carbofuron.

5.3 Effect of different treatments on nitrogen, phosphorous, potassium and pesticide content and NPK uptake in grain and straw of rice at harvest stage.

5.3.1 Nitrogen content

5.3.1.1 Nitrogen content in straw:

The nitrogen content in straw of rice was observed to be varied from 0.61 to 0.92 percent and 0.64 to 0.99 percent among the different treatments of rice in 2012 and 2013 respectively. The Nitrogen content in straw of rice was found to be significantly superior (0.92 and 0.99 percent in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF+ Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the nitrogen content in straw of rice as compared to pesticide untreated soil. The treatments receiving Phorate recorded the highest nitrogen content in straw of rice which was higher over Carbofuron. Nitrogen content in straw was found maximum in Medium black (0.86 to 0.99 percent) followed by Lateritic soil (0.73 to 0.81 percent) and was minimum in Coastal saline soil (0.61 to 0.70 percent).

5.3.1.2 Nitrogen content in grain

The nitrogen content in grain of rice was observed to be vary from 1.056 to 1.463 percent and 1.13 to 1.46 percent among the different treatments of rice in 2012 and 2013 respectively. The Nitrogen content in grain of rice was found to be significantly superior (1.463 and 1.460 percent in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF+ Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the nitrogen content in grain of rice as compared to pesticide untreated soil. The treatments receiving Phorate recorded the

highest nitrogen content in grain rice which was higher over Carbofuron. The nitrogen content in grain of rice was found to be maximum in Medium black (1.383 to 1.463 percent) followed by Lateritic soil (1.186 to 1.290 percent) and was minimum in Coastal saline soil (1.056 to 1.16 percent).

5.3.2 Phosphorous content

5.3.2.1 Phosphorous content in straw:

The phosphorous content in straw of rice was observed to be varied from 0.150 to 0.243 percent and 0.148 to 0.231 percent among the different treatments of rice at harvest stage of rice in 2012 and 2013 respectively. The phosphorous content in straw of rice was found to be significantly superior (0.243 and 0.231 percent in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the phosphorous content in straw of rice as compared to pesticide untreated soil. The treatments receiving Phorate recorded the highest phosphorous content in straw of rice which was higher over Carbofuron. The phosphorous content in straw was found to be maximum in Medium black (0.207 to 0.243 percent) followed by Lateritic soil (0.173 to 0.194 percent) and was minimum in Coastal saline soil (0.148 to 0.174 percent).

5.3.2.2 Phosphorous Content in grain

The phosphorous content in grain of rice was observed to be varied from 0.110 to 0.162 percent and 0.116 to 0.192 percent among the different treatments of rice in 2012 and 2013 respectively. The phosphorous content in grain of rice was found to be significantly superior (0.162 and 0.192 percent in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the phosphorous content in grain rice as compared to pesticide untreated treatment. The treatments receiving Phorate

recorded the highest the phosphorous content in grain rice which was higher over Carbofuron .The phosphorous content in grain rice was found to be maximum in Medium black soil (0.152 to 0.192 percent) followed by Lateritic soil (0.138 to 0.160 percent) and was minimum in Coastal saline soil (0.110 to 0.129 percent).

5.3.3 Potassium content:

5.3.3.1 Potassium content in straw:

The potassium content in straw of rice was observed to be varied from 1.541 to 1.857 percent and 1.570 to 1.743 percent among the different treatments of rice in 2012 and 2013 respectively. The potassium content in straw rice was found to be significantly superior (1.857 and 1.743 percent in 2012 and 2013 respectively) in T₃ (Lateritic soil+ RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the potassium content in straw rice as compared to pesticide untreated soil. The treatments receiving Phorate recorded the highest potassium content in straw of rice which were higher over Carbofuron. Among the various soil types, potassium content in straw was found to be maximum in Lateritic (1.703 to 1.857 percent) followed by Coastal saline soil (1.690 to 1.746 percent) and was minimum in Medium black soil (1.541 to 1.576 percent).

5.3.3.2 Potassium Content in grain :

The potassium content in grain rice was observed to be varied from 0.243 to 0.297 percent and 0.232 to 0.192 percent among the different treatments of rice in 2012 and 2013 respectively. The potassium content in grain rice was found to be significantly superior (0.297 percent in 2012 and 0.306 percent in 2013) in T₉ (Coastal saline soil + Phorate + 100 per cent RDF) treatment. Application of pesticides (Carbofuron and Phorate) increased the potassium content in grain rice as compared to pesticide untreated soil. Among the various soil types, the maximum

potassium content in grain was found in Coastal saline soil (0.291 to 0.306 percent) followed by Lateritic (0.270 to 0.288 percent) and was minimum in Medium black soil (0.232 to 0.249 percent).

5.3.4.1 Pesticides content in grain

The pesticides content in grain rice was observed to be varied from 14.80 to 29.13 $\mu\text{g kg}^{-1}$ and 15.76 to 25.36 $\mu\text{g kg}^{-1}$ among the different treatments of rice in 2012 and 2013 respectively. The pesticides content in grain rice was found to be significantly superior (29.13 and 25.36 $\mu\text{g kg}^{-1}$ in 2012 and 2013) in (Medium black soil + RDF + Carbofuran) treatment in the both year of experiments. Among the pesticides, the treatments receiving Carbofuron (PI) recorded the highest pesticides content in grain rice which was higher over Phorate (PII) treated treatment irrespective of soil type. Among the various soil types, the studies of pesticides content in grain was found to be maximum (29.13 to 25.36 $\mu\text{g kg}^{-1}$ for PI and 23.56 to 22.4 $\mu\text{g kg}^{-1}$ for PII) in Medium black soil followed by Lateritic soil (20.56 $\mu\text{g kg}^{-1}$ to 21.43 $\mu\text{g kg}^{-1}$ for PI and 17.40 to 19.60 $\mu\text{g kg}^{-1}$ for PII) and was minimum (16.76 to 19.46 $\mu\text{g kg}^{-1}$ for PI and 14.80 to 115.76 $\mu\text{g kg}^{-1}$ for PII) in Coastal saline soil. The pesticides residue in grain was below the maximum residue limit (0.1 mg kg^{-1}) fixed by WHO and USEPA.

5.3.4.2 Pesticides content in straw:

The pesticides content in straw of rice was observed to be varied from 7.86 to 16.53 $\mu\text{g kg}^{-1}$ and 6.86 to 17.73 $\mu\text{g kg}^{-1}$ among the different treatments of rice in 2012 and 2013 respectively. The pesticides content in straw rice was found to be significantly superior (16.53 and 25.36 $\mu\text{g kg}^{-1}$ in 2012 and 2013 respectively) in (Medium black soil + RDF + Carbofuran) treatment. Among pesticide, the treatments receiving Carbofuron recorded the highest (16.53 to 9.37 $\mu\text{g kg}^{-1}$ and 10.50 to 17.73 $\mu\text{g kg}^{-1}$ in first and second year of experiment respectively) the pesticides content in straw of rice which were higher over Phorate treated treatment irrespective of soil type. The pesticides content in straw was found to be maximum in Medium black followed by Lateritic soil and was observed to be minimum in Coastal saline soil. The pesticides content

in straw was found to be maximum. (16.53 to 17.73 $\mu\text{g kg}^{-1}$ for PI and 13.76 to 14.93 $\mu\text{g kg}^{-1}$ for PII) in Medium black followed by Lateritic soil (12.53 to 13.63 $\mu\text{g kg}^{-1}$ for PI and 10.56 to 11.56 $\mu\text{g kg}^{-1}$ for PII) and was observed to be minimum (9.73 to 10.50 $\mu\text{g kg}^{-1}$ for PI and 7.86 to 8.86 $\mu\text{g kg}^{-1}$ for PII) in Coastal saline soil. The pesticides content in straw of rice in the present study was found below maximum residue limit (0.2 $\mu\text{g kg}^{-1}$) fixed by WHO and USEPA. .

5.3.4. Effect of different treatments on Nitrogen, phosphorous and potassium uptake by rice.

5.3.4.1 Nitrogen uptake

5.3.4.1.1 Nitrogen uptake by straw:

The nitrogen uptake by straw of rice was observed to be vary from 75.8 to 231.0 mg kg^{-1} and 81.9 to 253.2 mg kg^{-1} among the different treatments of rice in 2012 and 2013 respectively. The nitrogen uptake by straw rice was found to be significantly superior (231.0 mg kg^{-1} and 253.2 mg kg^{-1} in 2012 and 2013 respectively) in T_6 (Medium black soil + RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the nitrogen uptake by straw rice as compared to pesticide untreated soil. Among the pesticides, the treatments receiving Phorate recorded the highest nitrogen uptake by straw rice which was higher over Carbofuron. Among the various soil types studied, the nitrogen uptake by straw was found to be maximum in Medium black (184.8 to 253.2 mg kg^{-1}) followed by Lateritic soil (111.4 to 149.7 mg kg^{-1}) and was minimum in Coastal saline soil (75.8 to 93.9 mg kg^{-1}).

5.3.4.1.2 Nitrogen uptake by grain:

The nitrogen uptake by grain of rice was observed to be vary from 102.6 to 290.4 mg kg^{-1} and 104.9 to 271.8 mg kg^{-1} among the different treatments of rice in 2012 and 2013 respectively. The nitrogen uptake by grain rice was found to be significantly superior (290.4 and 271.8

mgkg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the nitrogen uptake by grain rice as compared to pesticide untreated soil. Among the pesticides, the treatments receiving Phorate recorded the highest nitrogen uptake by grain rice which was higher over Carbofuron. The nitrogen uptake by grain was found to be maximum in Medium black (252.6 to 290.4 mg kg⁻¹) followed by Lateritic soil (160.6 to 195.1 mg kg⁻¹) and was minimum Coastal saline soil (102.6 to 119.6 mg kg⁻¹).

5.3.4.1.3 Nitrogen uptake by total biomass of rice:

The nitrogen uptake by total biomass of rice was observed to be vary from 178.4 to 521.5 mg kg⁻¹ and 186.8 to 525.1 mgkg⁻¹ among the different treatments in 2012 and 2013 respectively. The nitrogen uptake in total biomass of rice was found to be significantly superior (521.5 and 525.1 mg kg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the nitrogen uptake by total biomass of rice in the soil as compared to pesticide untreated soil. Among the pesticides, the treatments receiving Phorate recorded the highest nitrogen uptake by total biomass which was higher over Carbofuron. Among the various soil types, the nitrogen uptake by total biomass of rice was found to be maximum in Medium black soil (445.0 to 525.1 mg kg⁻¹) followed by Lateritic soil (273.6 to 340.2 mg kg⁻¹) and was minimum in Coastal saline soil (178.4 to 213.6 mgkg⁻¹).

5.3.4.2 Phosphorous uptake by grain and straw of rice

5.3.4.2.1 Phosphorous uptake by rice straw:

The phosphorous uptake by straw of rice was observed to be varied from 18.84 to 61.09 mgkg⁻¹ and 19.02 to 59.23 mg kg⁻¹ among the different treatments of rice in 2012 and 2013 respectively. The phosphorous uptake by straw of rice was found to be significantly superior (61.05 and 59.23 mgkg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil+ RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the phosphorous uptake by straw of rice in the soil as compared to pesticide untreated soil. Among the pesticides, the treatments receiving Phorate recorded the highest phosphorous uptake by straw which was higher over Carbofuron. The phosphorous uptake by straw was found to be maximum in Medium black (43.69 to 61.09 mgkg⁻¹) soil followed by Lateritic soil (26.34 to 35.34 mgkg⁻¹) and was minimum in Coastal saline soil (18.84 to 22.89 mgkg⁻¹).

5.3.4.2.2 Phosphorous uptake by grain:

The phosphorous uptake by grain of rice was observed to be varied from 10.72 to 31.78 mgkg⁻¹ and 10.85 to 35.94 mgkg⁻¹ among the different treatments of rice in 2012 and 2013 respectively. The phosphorous uptake by grain of rice was found to be significantly superior (35.94 and 31.78 mgkg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased the phosphorous uptake by grain of rice as compared to pesticide untreated soil irrespective of soil type. Among the pesticides, the treatments receiving Phorate recorded the higher total phosphorous uptake by grain which was higher over Carbofuron. Among the various soil types, the phosphorous uptake by grain was found to be maximum in Medium black (28.62 to 35.94 mgkg⁻¹) followed by Lateritic soil (18.3 to 24.31 mgkg⁻¹) and was minimum in Coastal saline soil (10.85 to 13.41 mgkg⁻¹).

5.3.4.2.3 Phosphorous uptake by total biomass of rice:

The phosphorous uptake by total biomass of rice was observed to be varied from 29.56 to 92.87 mg pot⁻¹ and 29.87 to 95.18 mg kg⁻¹ among the different treatments of rice in 2012 and 2013 respectively. The phosphorous uptake by total biomass of rice was found to be

significantly superior (92.87 and 95.18 mg kg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Among the various soil types, the phosphorous uptake in grain was found to be maximum in Medium black (28.62 to 35.94 mgkg⁻¹) followed by Lateritic soil (18.3 to 24.31 mgkg⁻¹) and was minimum in Coastal saline soil (10.85 to 13.41 mgkg⁻¹). Application of pesticides (Carbofuron and Phorate) increased the phosphorous uptake by grain rice as compared to pesticide untreated soil irrespective of soil type. Among the pesticides, the treatments receiving Phorate recorded the higher the total phosphorous uptake by grain which was higher over Carbofuron.

5.3.4.3 Potassium uptakeby grain and straw of rice

5.3.4.3.1 Potassium uptake by straw:

The uptake of potassium by straw of rice was observed to be varied from 215.98 to 388.12 mg kg⁻¹ and 216.3 to 404.0 mg kg⁻¹among the different treatments of rice in 2012 and 2013 respectively.The uptake of potassium by straw of rice was found to be significantly superior (388.12 and 404.0 mg kg⁻¹in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment.Application of pesticides (Carbofuron and Phorate) increased uptake of potassium by straw of rice as compared to pesticide untreated soil. Among the pesticides, the treatments receiving Phorate recorded the highest uptake of potassium by straw of rice over Carbofuron. Among the various soil types,uptake of potassium by straw was found to be maximum in Medium black (326.30 to 404.0mgkg⁻¹) followed by Lateritic soil (262.9 to 337.23mgkg⁻¹) and was minimum in Coastal saline soil (215.98 to 231.5mg kg⁻¹).

5.3.4.3.2 Potassium uptake by grain:

The uptake of potassium by grain rice was observed to be varied from 28.29 to 49.59 mg kg⁻¹ and 27.81 to44.46 mg kg⁻¹among the different treatments of rice in 2012 and 2013 respectively.The uptake of potassium by grain rice was found to be significantly superior (49.59

and 44.46 mg kg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil+ RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased uptake of potassium by grain rice as compared to pesticide untreated. Among the pesticides, the treatments receiving Phorate recorded the highest uptake of potassium by grain of rice over Carbofuron. Among the various soil types, uptake of potassium by grain was found to be maximum in Medium black (41.28 to 49.59 mgkg⁻¹) followed by Lateritic soil (41.28 to 45.59 mgkg⁻¹) and was minimum in Coastal saline (27.81 to 31.21 mgkg⁻¹).

5.3.4.3.3 Uptake of potassium by total biomass:

The uptake of potassium by total biomass of rice was observed to be varied from 244.2 to 437.7 mg kg⁻¹ and 244.1 to 448.4 mg kg⁻¹ among the different treatments of rice in 2012 and 2013 respectively. The uptake of potassium by total biomass of rice was found significantly superior (437.7 and 404.0 mgkg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Application of pesticides (Carbofuron and Phorate) increased uptake of potassium by total biomass of rice as compared to pesticide untreated soil. Among the pesticides, the treatments receiving Phorate recorded the highest uptake of potassium by total biomass of rice which was higher over Carbofuron. Among the various soil types, uptake of potassium by total biomass of rice was found to be maximum in Medium black (371.9 to 448.4 mgkg⁻¹) followed by Lateritic soil (299.9 to 380.3 mgkg⁻¹) and was minimum in Coastal saline (244.1 to 262.7 mgkg⁻¹).

Irrespective of soil type, application of pesticides (Carbofuron and Phorate) showed positive and stimulating effect on nutrient uptake (N, P and K) by rice. The Phorate was better in contributing the N, P and K uptake by rice over Carbofuron.

5.4. Effect of different treatments on availability of primary nutrient and Pesticides residues to soil at different growth stages of rice crop.

5.4.1 Effect of different treatments on availability nitrogen to soil at different growth stages of rice crop.

The periodic observations of available N in soil showed that the content varied from 308.6 to 363.0 kg ha⁻¹, 340.9 to 383.4 kg ha⁻¹, 296.9 to 341.9 kg ha⁻¹ and 284.8 to 342.4 kg ha⁻¹ at 30, 60, 90DAT and at harvest stage respectively in 2012 among the different treatments of rice. In 2013, its content varied from 310.7 to 357.1 kg ha⁻¹, 334.2 to 376.2 kg ha⁻¹, 302.0 to 330.1 kg ha⁻¹ and 279.4 to 348.3 kg ha⁻¹ at 30, 60, 90DAT and at harvest stage respectively among the different treatments of rice.

The available nitrogen at 30DAT was found to be significantly superior (363.0 kg ha⁻¹ and 352.0 kg ha⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF + Phorate) treatment. At 60DAT the available nitrogen was found significantly higher (383.44 kg ha⁻¹) in T₃ (Lateritic soil + RDF + Phorate) treatment in 2012 however in 2013 it was found significantly higher (376.20 kg ha⁻¹) in T₆ (Medium black soil + RDF + Phorate) treatment respectively. At 90DAT the available nitrogen was found significantly superior (341.9 kg ha⁻¹ and 327.2 kg ha⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF + Phorate) treatment. At harvest stage the available nitrogen was found significantly superior (342.4 kg ha⁻¹ and 348.3 kg ha⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF + Phorate) treatment.

Available nitrogen in soil attains a highest peak at 60DAT stage in all the treatments thereafter it showed declining trend up to 90DAT. The Phorate was more effective as compared to Carbofuron in contributing to the higher value of available N content.

5.4.2 Effect of treatments on available Phosphorous (kg ha⁻¹)

The periodic observations of available P₂O₅ content in soil showed that the content varied from 12.9 to 30.5, 15.60 to 33.10, 13.4 to 31.9 and 11.8 to 28.2 kg ha⁻¹ at 30, 60, 90DAT and at harvest stage respectively among the different treatments of rice in 2012 while in 2013, its content varied from 13.1 to 29.4, 16.0 to 31.6, 13.8 to 29.8 kg ha⁻¹ and 12.0 to 26.76 kg ha⁻¹ at 30, 60, 90DAT and at harvest stage respectively.

The available P_2O_5 at 30DAT was found to be significantly superior (30.5 kg ha^{-1} and 29.4 kg ha^{-1} in 2012 and 2013 respectively) in T_9 (Coastal saline soil + RDF + Phorate) treatment. The available P_2O_5 at 60DAT was found to be significantly superior (33.10 kg ha^{-1} and 31.6 kg ha^{-1} in 2012 and 2013 respectively) in T_9 (Coastal saline soil + RDF + Phorate) treatment. At 90DAT the available P_2O_5 was found to be significantly superior (31.9 and 29.8 kg ha^{-1} in 2012 and 2013 respectively) in T_9 (Coastal saline soil + RDF + Phorate) treatment. The available P_2O_5 at harvest stage was found to be significantly superior (28.2 kg ha^{-1} and 26.5 kg ha^{-1} in 2012 and 2013 respectively) in T_9 (Coastal saline soil + Phorate + 100 percent RDF) treatment.

Among the different growth stages, maximum available P_2O_5 content was recorded at 60 DAT stage in all the treatments thereafter it showed declining trend at harvest stage.

5.4.3 Effect of treatments on available Potassium (kg ha^{-1})

The periodic observations of available K_2O content in soil showed that the content varied from 297.3 to $1087.7 \text{ kg ha}^{-1}$, 286.1 to $1099.1 \text{ kg ha}^{-1}$, 271.1 to $1138.2 \text{ kg ha}^{-1}$ and 269.0 to $1087.6 \text{ kg ha}^{-1}$ at 30, 60, 90DAT and at harvest stage respectively in 2012. In 2013, its content varied from 295.1 to $1072.3 \text{ kg ha}^{-1}$, 286.1 to $1102.9 \text{ kg ha}^{-1}$, 268.2 to $1126.0 \text{ kg ha}^{-1}$ and 261.0 to $1078.6 \text{ kg ha}^{-1}$ at 30, 60, 90DAT and at harvest stage respectively.

At 30DAT the available K_2O was found to be significantly superior ($1087.7 \text{ kg ha}^{-1}$ and $1072.3 \text{ kg ha}^{-1}$ in 2012 and 2013 respectively) in T_9 (Coastal saline soil + RDF + Phorate). The available K_2O at 60 DAT was found to be significantly superior ($1099.1 \text{ kg ha}^{-1}$ and $1102.9 \text{ kg ha}^{-1}$ in 2012 and 2013 respectively) in T_9 (Coastal saline soil + RDF + Phorate) treatment. At 90 DAT the available K_2O was found to be significantly superior ($1138.2 \text{ kg ha}^{-1}$ and $1126.09 \text{ kg ha}^{-1}$ in 2012 and 2013 respectively) in T_9 (Coastal saline soil + RDF + Phorate)

treatment. The available K_2O at harvest stage was found to be significantly superior ((1087.6 $kg\ ha^{-1}$ and 1078.8 $kg\ ha^{-1}$ in 2012 and 2013 respectively) in T_9 (Coastal saline soil + RDF + Phorate) treatment.

Maximum available K_2O content was recorded at 30DAT stage in Lateritic soil and Medium black soil thereafter declined trend upto 90DAT in Lateritic soil and Medium black soil. However in case of Coastal saline soil the available K_2O content in soil increased from 30DAT to 90DAT and found highest at 90DAT stage. Combined application of graded dose of fertilizers along with pesticides increased the available K_2O in soil over treatment RDF only in the all soil type.

5.4.4 Effect of treatments on residues of pesticides in soil in soil at different growth stages

The periodic observations of pesticides residues in soil showed that its content varied from 123 to 1196 $\mu g\ kg^{-1}$, 54.1 to 92.3 $\mu g\ kg^{-1}$, 25.9 to 86.2 $\mu g\ kg^{-1}$ and 1.12 to 3.70 $\mu g\ kg^{-1}$ at 30, 60, 90DAT and at harvest stage respectively in 2012. In 2013, its content varied from 185.1 to 1127 $\mu g\ kg^{-1}$, 49.26 to 99.5 $\mu g\ kg^{-1}$, 21.5 to 89.93 $\mu g\ kg^{-1}$ and 1.18 to 3.5 $\mu g\ kg^{-1}$ at 30, 60, 90DAT and at harvest stage respectively.

Pesticides (Carbofuron) residues content at 30 DAT sampling was recorded significantly highest (1196 $\mu g\ kg^{-1}$ and 1127 $\mu g\ kg^{-1}$ in 2012 and 2013 respectively) in Medium black soil with the application of (Carbofuron (PI) +RDF). Pesticides (Carbofuron) residues content at 60 DAT sampling was recorded significantly highest (92.3 $\mu g\ kg^{-1}$ and 99.5 $\mu g\ kg^{-1}$ in 2012 and 2013 respectively) in Medium black soil with the application of (Carbofuron (PI) +RDF). Pesticides (Carbofuron) residues content at 90DAT sampling was recorded significantly highest (86.2 $\mu g\ kg^{-1}$ and 89.9 $\mu g\ kg^{-1}$ in 2012 and 2013 respectively) in Medium black soil with the application of (Carbofuron (PI) +RDF). Pesticides (Carbofuron) residues content at harvest stage sampling was recorded significantly highest (3.70 $\mu g\ kg^{-1}$ and 3.50 $\mu g\ kg^{-1}$ in 2012 and 2013 respectively) in Medium black soil with the application of (Carbofuron (PI) +RDF).

Among the various growth stages of rice, the pesticide residue content was recorded highest at 30DAT and afterwards it showed decreasing trend. Among all the soil types, the pesticide residue (PI and PII) content in soil was found to be maximum in Medium black soil followed by Lateritic soil and was minimum in Coastal saline soil. Among the two pesticides (PI and PII) treatment in the present study, the Carbofuron (PI) pesticide residue content was found higher as compared to Phorate (PII) content irrespective of soil at all the stages of rice growth.

5.5 Effect of treatments on changes in NPK fractions in soil under rice crop.

5.5.1. Effect of treatments on changes in N fractions in soil under rice crop.

The changes in the content of nitrogen fractions viz. ammonical-N, nitrate-N and total N (ammonical-N + nitrate-N) of soil at harvest of crop as influenced by various treatments.

5.5.1.1 Ammonical-N fractions

The ammonical-N in soil was observed to be varied from 31.2 to 43.7 mgkg⁻¹ and 28.2 to 45.13 mgkg⁻¹ among the different treatments at harvest of rice in 2012 and 2013 respectively. The ammonical-N was found to be significantly superior (43.76 and 45.13 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil +RDF +Phorate) treatment.

Irrespective of soil type the ammonical-N in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increases ammonical-N content as compared to pesticide untreated soil irrespective of soil type. Among the two pesticides (PI and PII), the Phorate (PII) receiving treatments recorded the highest ammonical-N in soil which was

significantly superior over Carbofuron. Among the various soil types, ammonical-N was found to be maximum Coastal saline (39.1 to 45.13 mg kg⁻¹) followed by Lateritic soil (32.4 to 43.6 mg kg⁻¹) and was minimum in Medium black soil (28.2 to 42.4 mg kg⁻¹).

5.5.1.2 Nitrate-N fractions:

The nitrate-N in soil was observed to be varied from 17.8 to 28.6 mg kg⁻¹ and 15.8 to 29.5 mg kg⁻¹ among the different treatments at harvest of rice in 2012 and 2013 respectively. The nitrate-N content was found to be significantly superior (28.6 and 29.5 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF+ Phorate) treatment.

Irrespective of soil type the nitrate-N in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the nitrate-N content in the soil at harvest of rice than pesticide untreated soil irrespective of soil type. Among the two pesticides (PI and PII), the Phorate (PII) receiving treatments recorded the highest nitrate-N in soil which was significantly superior over Carbofuron. Among the various soil type under study, nitrate-N content was found to be maximum in Coastal saline (25.2 to 29.5 mg kg⁻¹) followed by Lateritic soil (17.4 to 27.7 mg kg⁻¹) and was minimum in Medium black soil (15.3 to 25.4 mg kg⁻¹).

5.5.1.3 Total (ammonical + nitrate)-N of soil

Total N fraction is the sum of fractions ammonical-N and nitrate-N. From the data it is revealed that the total (ammonical+nitrate)-N in soil was observed to be varied from 49.0 to 72.36 mg kg⁻¹ and 44.0 to 74.63 mg kg⁻¹ among the different treatments in 2012 and 2013 respectively. The total (ammonical + nitrate)-N was found to be highest (72.36 and 74.63 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF + Phorate) treatment.

Irrespective of soil type the total (ammonical + nitrate)-N in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the total (ammonical + nitrate)-N content in the soil as compared to pesticide untreated soil irrespective of soil type. Among the two pesticides (PI and PII), the Phorate (PII) receiving treatments recorded the highest total (ammonical + nitrate)-N in soil than Carbofuron. Ammonical-N content in soil was found higher in all treatments as compared to nitrate-N content in soil due to submerged conditions. Among the various soil types, maximum total (ammonical + nitrate)-N content was found to be maximum in Coastal saline soil (64.3 to 74.63 mg kg⁻¹) followed by Medium black soil (49.8 to 70.8 mg kg⁻¹) and was minimum in Lateritic soil (44.0 to 67.8 mg kg⁻¹).

5.5.2. Effect of treatments on changes in phosphorous fraction in soil under rice crop

The changes in the inorganic P-fractions viz. sal-P (Saloid-P), Al-P, Fe-P, Ca-P, occluded-P, reductant soluble-P and total inorganic-P of soil at harvest of crop as influenced by various treatments summarized below.

5.5.2.1 Saloid-P fractions:

The saloid-P in soil was observed to be vary from 7.3 to 14.1 mg kg⁻¹ and 5.7 to 13.8 mg kg⁻¹ in 2012 and 2013 respectively among the different treatments at harvest of rice. The saloid-P was found to be significantly higher (14.1 and 13.8 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil+ RDF + Phorate) treatment.

Irrespective of soil type the saloid-P in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased saloid-P content as compared to pesticide untreated soil. Among the two pesticides (PI and PII), the Phorate (PII) receiving treatments recorded the highest saloid-P in soil which was significantly superior over Carbofuron.

Among the various soil types, saloid-P was found to be maximum in Coastal saline (11.9 to 14.1 mgkg⁻¹) followed by Medium black soil (8.1 to 10.5 mgkg⁻¹) and was minimum in Lateritic soil (5.7 to 9.2 mgkg⁻¹). The saloid bound-P fraction is the least among the all fractions in different soil types.

5.5.2.2 Aluminium-bound P (Al-P)

The Al-P in soil was observed to be varied from 55.5 to 98.2 mg kg⁻¹ and 52.5 to 96.5 mgkg⁻¹ in 2012 and 2013 respectively among the different treatments at harvest of rice. The Al-P content was found to be significantly superior (98.2 and 96.5 mg kg⁻¹ in 2012 and 2013 respectively) in T₃ (Lateritic soil + RDF + Phorate) treatment.

Irrespective of soil type the Al-P in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the Al-P content in the soil at harvest of rice as compared to pesticide untreated soil. Among the various soil types, Al-P was observed to be maximum in Lateritic soil (88.2 to 98.2 mg kg⁻¹) followed by Coastal saline soil (56.4 to 65.8 mg kg⁻¹) and was minimum in Medium black soil (52.5 to 62.4 mg kg⁻¹).

5.5.2.3 Iron-bound (Fe - P)

The Fe-P in soil was observed to be varied from 71.7 to 184.1 mg kg⁻¹ and 65.0 to 176.7 mg kg⁻¹ in 2012 and 2013 respectively among the different treatments at harvest of rice. The Fe-P was found to be significantly superior (184.1 and 172.2 mg kg⁻¹ in 2012 and 2013 respectively) in T₃ (Lateritic soil + RDF + Phorate) treatment.

Irrespective of soil type the Fe-P in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the Fe-P content in the soil at harvest of rice as compared to pesticide untreated soil.

Among the various soil types, Fe-P was found to be maximum in Lateritic soil (161.1 to 184.1 mg kg⁻¹) followed by Medium black soil (74.0 to 86.1 mg kg⁻¹) and was minimum in Coastal saline soil (65 to 80.7 mg kg⁻¹).

5.5.2.4 Calcium-bound (Ca-P)

The Ca-P in soil was observed to be varied from 36 to 141.7 mg kg⁻¹ and 34.4 to 149.7 mg kg⁻¹ in 2012 and 2013 respectively among the different treatments at harvest of rice. The Ca-P content was found to be significantly superior (147 and 149.7 mg kg⁻¹ in 2012 and 2013 respectively) in T₆ (Medium black soil + RDF + Phorate) treatment. Irrespective of soil type the Ca-P in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the Ca-P content in the soil at harvest of rice as compared to pesticide untreated soil. Among the two pesticides (PI and PII), the Phorate (PII) receiving treatments recorded the highest Ca-P in soil which was significantly superior over Carbofuron.

The Ca-P fraction was found to be maximum (126.5 to 149.7 mg kg⁻¹) in Medium black soil followed by Coastal saline soil (125.4 to 135.5 mg kg⁻¹) and was minimum (34.4 to 39.8 mg kg⁻¹) in Lateritic soil.

5.5.2.5 Occluded-P

The occluded-P in soil was observed to be varied from 44.6 to 100.4 mgkg⁻¹ and 45.6 to 96.0 mgkg⁻¹ in 2012 and 2013 respectively among the different treatments at harvest of rice. The occluded-P was found to be significantly superior (100.4 and 96.0 mgkg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF + Phorate) treatment.

Irrespective of soil type the occluded-P in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the occluded-P content in the soil at harvest of rice as compared to pesticide untreated soil. The occluded-P fraction was found to be maximum in Coastal saline soil (89.5 to 100.4 mg kg⁻¹) followed by Lateritic soil (78.1 to 85.1 mg kg⁻¹) and was minimum in Medium black soil (44.6 to 53.6 mg kg⁻¹).

5.5.2.6 Reductant soluble-P

The reductant soluble-P in soil were observed to be varied from 93.0 to 142.4 mgkg⁻¹ and 95.5 to 142.1 mgkg⁻¹ in 2012 and 2013 respectively among the different treatments at harvest of rice. The reductant soluble-P was found to be significantly superior (142.4 and 142.1 mgkg⁻¹ in 2012 and 2013 respectively) in T₃ (Medium black soil + RDF + Phorate) treatment which was found at par with treatment T₂.

Irrespective of soil type the reductant soluble-P in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the reductant soluble-P content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type.

The reductant soluble-P fraction was found to be maximum in Lateritic soils (128.4 to 142.4 mg kg⁻¹) followed by Medium black soil (97.6 to 109.4 mg kg⁻¹) and was minimum in Coastal saline soils (93.0 to 102.5 mg kg⁻¹).

5.5.2.7 Total inorganic - P

The total inorganic-P in soil was observed to be varied from 405.6 to 558.9 mg kg⁻¹ and 412.7 to 546.8 mg kg⁻¹ in 2012 and 2013 respectively among the different treatments at harvest of rice. Total inorganic-P was found to be highest (558.9 and 546.8 mg kg⁻¹ in 2012 and 2013 respectively) in T₃ (Lateritic soil+ RDF+ Phorate) treatment.

Irrespective of soil type the total inorganic-P in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the total inorganic-P content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Among the pesticides, the Phorate receiving treatments recorded the highest total inorganic-P in soil at harvest of rice than Carbofuron treatment irrespective of soil type. The total inorganic P was found to be maximum in Lateritic soil (499.4 to 558.9 mg kg⁻¹) followed by Medium black soil (444.2 to 499.2 mg kg⁻¹) and was minimum in Coastal saline soil (405.6 to 469 mg kg⁻¹) in the present study.

Among the various inorganic P-fractions in Lateritic soil under rice was observed to be maximum of Fe-P (161.1-184.1 mg kg⁻¹), reductant soluble-P (128.1 to 142.2 mg kg⁻¹), Al-P (88.2 to 98.2 mg kg⁻¹), occluded-P (78.1 to 85.1 mg kg⁻¹), Ca-P (34.4 to 39.8 mg kg⁻¹), saloid-P (5.7 to 9.2 mg kg⁻¹) in decreasing trend.

Among the various inorganic P-fractions in Medium black soil under rice crop, was observed to be maximum of Ca-P (126.5 to 149.7 mg kg⁻¹), reductant soluble-P (97.6 to 109.4 mg kg⁻¹), Fe-P (74.0 to 86.1 mg kg⁻¹), Al-P (52.5 to 62.4 mg kg⁻¹), occluded-P (44.6 to 53.6 mg kg⁻¹), saloid-P (7.2 to 11.5 mg kg⁻¹) in decreasing trend.

Among the various inorganic P-fractions in Coastal saline soil under rice crop, was observed to be maximum of Ca-P (125.4 to 135.5 mg kg⁻¹), reductant soluble-P (93.0 to 102.5 mg kg⁻¹), occluded-P (89.5 to 100.4 mg kg⁻¹), Fe-P (65.0 to 80.7 mg kg⁻¹), Al-P (56.4 to 65.8 mg kg⁻¹), saloid-P (11.9 to 14.1 mg kg⁻¹) in decreasing trend.

5.5.3. Effect of treatments on changes in potassium fractions in soil under rice crop.

The changes in the inorganic potassium fractions water-soluble-K, exchangeable-K, non-exchangeable-K, and available-K (water-soluble-K + exchangeable-K) of soil under rice crop at harvest stage as influenced by various treatments summarized below.

5.5.3.1 Water soluble - K fractions:

The water soluble-K in soil was observed to be varied from 4.8 to 99.1 mg kg⁻¹ and 3.2 to 92.9 mg kg⁻¹ among the different treatments at harvest of rice in 2012 and 2013 respectively. The water soluble-K was found to be significantly superior (99.1 and 92.9 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF + Phorate) treatment which was found at par with T₇ and T₈.

Irrespective of soil type the water soluble-K in soil increased after harvest than its corresponding initial values due to application of RDF. Among the various soil types, water soluble-K was observed to be maximum in Coastal saline (90.1 to 99.1 mg kg⁻¹) followed by Medium black (5.3 to 7.9 mg kg⁻¹) and was lowest in Lateritic soil (3.2 to 5.8 mg kg⁻¹). The water soluble-K fraction is the least among all K fractions in different soil types.

5.5.3.2 Exchangeable - K fractions:

The exchangeable-K in soil was observed to be varied from 95.2 to 308.0 mg kg⁻¹ and 93.86 to 312.0 mg kg⁻¹ among the different treatments at harvest of rice in 2012 and 2013 respectively. The exchangeable-K was found to be significantly superior (308.0 and 312 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil + RDF + Phorate) treatment.

Irrespective of soil type the exchangeable-K in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the exchangeable-K content in the soil at harvest of rice as compared to

pesticide untreated irrespective of soil type. Among the various soil types, exchangeable-K is observed to be maximum in Coastal saline (305.9 to 312.0 mg kg⁻¹) followed by Medium black (96.66 to 112.7 mg kg⁻¹) and was minimum in Lateritic soil (93.86 to 96.36 mg kg⁻¹).

5.5.3.3 Non exchangeable- K fractions:

The non exchangeable-Kin soil was observed to be varied from 361.4 to 483.4 mg kg⁻¹ and 365.2 to 472.5 mg kg⁻¹ among the different treatments at harvest of rice in 2012 and 2013 respectively. The non exchangeable-K was found to be significantly superior (483.40 and 472.5 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil+ RDF + Phorate) treatment which was found at par with T₈.

Irrespective of soil type the non exchangeable-K in soil increased after harvest than its corresponding initial values due to application of RDF. Among the various soil types, non exchangeable-K is observed to be maximum in Coastal saline (463.7 to 483.4 mg kg⁻¹) followed by Medium black (401.8 to 427.8 mg kg⁻¹) and was minimum in Lateritic soil (361.4 to 381.0 mg kg⁻¹).

5.5.3.4 Available-K Fractions:

The available Kin soil was observed to be varied from 95.2 to 308.0 mg kg⁻¹ and 93.86 to 312.0 mg kg⁻¹ among the different treatments at harvest of in 2012 and 2013 respectively. The available-K was found to be significantly superior (308.0 and 312 mg kg⁻¹ in 2012 and 2013 respectively) in T₉ (Coastal saline soil+ RDF + Phorate) treatment.

Irrespective of soil type the available K in soil increased after harvest than its corresponding initial values due to application of RDF. Application of pesticides (Carbofuron and Phorate) increased the available-K content in the soil at harvest of rice as compared to pesticide untreated soil irrespective of soil type. Among the two pesticides (PI and PII), the Phorate (PII) receiving treatments recorded the highest

available K in soil which was significantly superior over Carbofuron. Among the various soil types, available-K was observed to be maximum in Coastal saline (400.7 to 407.2 mg kg⁻¹) followed by Medium black (111.4 to 121.1 mg kg⁻¹) and was minimum in Lateritic soil (97.06 to 102.1 mg kg⁻¹).

Among the various inorganic K-fractions in Lateritic soil under rice crop, was observed to be maximum of non-exchangeable-K,(361.4-381.0 mg kg⁻¹),available-K (water soluble-K + exchangeable-K)(97.06 to 102.1mg kg⁻¹), exchangeable-K(93.8 to 96.3mg kg⁻¹),water soluble - K (3.2 to 5.8 mg kg⁻¹) in decreasing trend.

Among the various inorganic K-fractions in Medium black soil under rice crop, was observed to be maximum of non-exchangeable-K(401.8 to 427.8mg kg⁻¹), available-K (water-soluble-K + exchangeable-K)(101.9 to 121.1mg kg⁻¹),exchangeable-K(96.6 to 112.7mg kg⁻¹),water soluble-K (3.2 to 5.8mg kg⁻¹) in decreasing trend.

Among the various inorganic K-fractions in Coastal saline soil under rice crop, was observed to be maximum of non-exchangeable-K(463.7 to 483.4mg kg⁻¹), available-K (water-soluble-K + exchangeable-K)(400.7 to 407.2mg kg⁻¹), exchangeable-K(305.9 to 312.0 mg kg⁻¹), water soluble-K (90.1 to 99.1mg kg⁻¹) in decreasing trend.

5.6 Correlationship between soil physic-chemical properties with available N, P, K and pesticides residues in soil under rice

The correlationship between soil physicochemical properties with available N, P, K and pesticides residues in soil under rice were also worked out. A highly significant and negative relationship of sand, IR and organic carbon was seen with available-N (at 90DAT and AH)

whereas clay and CEC were correlated significantly and positively. A highly significant and negative relationship of sand, IR and organic carbon was seen with available P whereas silt, clay, pH and CEC showed a highly significant and positive relationship. A highly significant and negative relationship of sand, organic carbon and IR was seen with available-K, whereas silt, clay pH and CEC showed a highly significant and positive relationship. A negative relationship of clay and EC was seen with pesticides residues.

B. Experiment-II

5.7 Effect of soil types on pesticides leaching losses and their movement in soil profile at different depth.

5.7.1. Leaching losses of pesticides from different soil profiles as affected by various treatments.

The leaching losses of the pesticides in the percolates from soil column at various DAA (30, 60 and 90 DAA (Day after application) to soil were analyzed for both the pesticides viz., PI (Carbofuron) and PII (Phorate). The leaching losses of pesticides from soil columns observed to vary from 84.7 to 724.9 $\mu\text{g column}^{-1}$, 61.0 to 821.0 $\mu\text{g column}^{-1}$ among the different treatments in 2012 and 2013 respectively.

The column which was kept for 90DAA (days after application) of pesticides showed maximum value of pesticides in percolates which was similar to column kept for 60 days (60 DAA). The pesticides were present in the pooled leachate upto 42-49 days drawn at weekly interval however no pesticides residue was found from 50 days onwards. The leaching losses of pesticides were found to be significantly higher (724.9 and 821 $\mu\text{g column}^{-1}$ in 2012 and 2013) in (Lateritic soil + Carbofuron + 90 DAA). The maximum leaching loss of pesticides was observed in Lateritic soils (7.41 to 11.14 percent of applied quantity) followed by Medium black soil (3.75 to 6.78 percent) and least in Coastal saline soil (1.88 to 3.82 percent) when the columns were kept for 90 days. Among the pesticides (PI) and (PII) treatments under study, the Carbofuron (PI) recorded the higher (3.46 to 11.14 percent) leaching losses at all the sampling period over Phorate (PII) (1.88 to 8.24 percent).

5.7.2. Effect of treatments on pesticides residues in soil ($\mu\text{g kg}^{-1}$)

The downward movement behavior of pesticides (PI and PII) in different soil types was studied using soil columns. The mobility of applied pesticide residues in various soil types using soil columns at different depth of soil profiles viz. 0-30, 30-60, 60-90 cm as sampled after 30, 60 and 90DAA are summarized below

In different soil type under study the Carbofuron (PI) content at various depths were analyzed. The range of Carbofuron (PI) residue in soil column in 2012 was observed to be 81.0 to 1414.0 $\mu\text{g kg}^{-1}$, 18 to 83.0 $\mu\text{g kg}^{-1}$, 5.0 to 111.0 $\mu\text{g kg}^{-1}$, at 0-30cm, 30-60cm, and 60-90cm depth respectively. And in the year 2013 the values were in the range of 73.0 to 1561.0 $\mu\text{g kg}^{-1}$, 13.0 to 75.0 $\mu\text{g kg}^{-1}$ and 3.0 to 102.0 $\mu\text{g kg}^{-1}$ at 0-30cm, 30-60cm, and 60-90cm depth respectively.

The depth wise Phorate (PII) residue in soil column at different soil type in 2012 at depth 0-30cm, 30-60cm, and 60-90cms was in the range of 44.0 to 816.0 $\mu\text{g kg}^{-1}$, 12.0 to 42.0 $\mu\text{g kg}^{-1}$ and 0.9 to 51.0 $\mu\text{g kg}^{-1}$ respectively. The values were in the range of 40.0 to 891.0 $\mu\text{g kg}^{-1}$, 10.0 to 41.0 $\mu\text{g kg}^{-1}$ and 1.2 to 48.0 $\mu\text{g kg}^{-1}$ at 0-30 cm, 30-60 cm, and 60-90 cm depth respectively during the year 2013.

Among the different soil types, the pesticides residues content at 0-30cm depth was found to be maximum in Medium black soil followed by Lateritic soil and Coastal saline soil. On the other hand, at 30-60cm and 60-90cm depth it was found maximum in Lateritic soils than compared to other two soil types due to higher leaching losses. Accumulation of leached pesticides in the lower layer from upper layer of profile (columns) was found more in Lateritic soil than Medium black and Coastal saline soil. Pesticide sorption was greater in surface horizons than in subsoil. The downward movement of Carbofuron (PI) in downward layer of soil profile was found maximum than Phorate (PII).

Among the two pesticides, the higher amount of Carbofuron (percent of applied quantity) residues reached up to the lower layer (30-60cm and 60-90cm) in soil than Phorate due to its higher solubility.

Conclusion

It can be concluded from the results, that out of three soils studied the leaching losses of nutrient (N and P) and pesticides observed to maximum in Lateritic soil followed by Medium black soil and was minimum in Coastal saline soil during the various growth stages of rice. It can be also concluded that application of pesticides increased the nutrient availability in all three soil. Maximum leaching losses of nutrients and pesticides were observed upto 30 DAT sampling. The study on persistence of pesticides in soil under rice crop is concerned; the results indicated that maximum residues occurred in Medium black soil.

The portion of nutrients applied through fertilizers and pesticides gets fixed in the form of various fractions and becomes unavailable to crop. The fractions of N, P and K at harvest stage of rice affected due to treatments were also quantified. Ammonical-N fraction in all the three soil types was found dominant over nitrate-N because of submerged condition. In case of P-fractions, the Lateritic soil dominated by Fe-P however Medium black and Coastal saline soil dominated by Ca-P. As regards to K-fractions, all the three soil types were dominated by non-exchangeable K.

The correlationship between soil physicochemical properties with available N, P, K and pesticides residues in soil under rice were also worked out. A highly significant and negative relationship of sand, IR and organic carbon was seen with available-N (at 90DAT and AH) whereas clay and CEC was correlated significantly and positively. A highly significant and negative relationship of sand, IR and organic carbon

was seen with available P whereas silt, clay pH and CEC showed a highly significant and positive relationship. A highly significant and negative relationship of sand, organic carbon and IR was seen with available-K, whereas silt, clay, pH and CEC showed a highly significant and positive relationship. A negative relationship of clay and EC was seen with pesticides residues.

The results of the leaching column experiments concluded that, the maximum pesticides leaching loss through percolates occurred in Lateritic soil and minimum in Coastal saline soil. Among the two pesticides studied, the losses of Carbofuron were found more than Phorate due to its higher solubility in water. The pesticides residues in surface (0-30cm) soil of leaching column was found maximum at 30th day sampling thereafter it gradually decreased up to 90th days of sampling due to degradation and leaching losses. The vertical downward movement of pesticides was seen maximum in Lateritic soil and least in the Coastal saline soil. Carbofuran moved faster through the layer than Phorate.

Table : Physical properties of different types of soil profiles studied.

Soil depth cm	Mechanical Composition (%)			Textural class	Bulk density Mg m ⁻³	Porosity %	IR cm hr ⁻¹
	Sand	Silt	Clay				
Lateritic soil-Location Dapoli							
0-30	59.52	14.72	25.76	Sandy clay loam	1.25	38.10	2.1
30-60	37.00	28.00	35.00	Clay loam	1.28	35.40	
60-90	32.52	36.00	31.48	Clay loam	1.28	35.30	
Medium black soil - Location Karjat							
0-30	39.88	24.36	35.76	Clay loam	1.27	28.65	1.4
30-60	38.96	22.00	39.04	Clay loam	1.29	22.62	

60-90	42.96	24.00	33.04	Clay loam	1.22	25.62	
Coastal saline soil - Location Panvel							
0-30	33.04	20.48	46.48	Clay	1.29	20.60	0.9
30-60	40.96	28.00	31.04	Clay loam	1.24	22.35	
60-90	44.96	30.00	25.04	Loam	1.20	25.60	

Table : Chemical properties of different types of soil profiles studied.

Soil depth (cm)	pH	EC dS m ⁻¹	Organic carbon %	Organic matter %	CEC Cmole(P ⁺)kg ⁻¹	Av. Nitrogen kg ha ⁻¹	Av. P ₂ O ₅ kg ha ⁻¹	Av. K ₂ O kg ha ⁻¹	DTPA extractable micronutrient (mg kg ⁻¹)			
									Zn	Cu	Mn	Fe
Lateritic soil -Dapoli												
0-30	5.80	0.08	1.8	3.10	28.40	298.8	9.1	229.8	3.21	4.46	47.97	48.30
30-60	6.10	0.09	0.57	0.982	31.69	311.4	9.0	249.3	3.60	3.25	41.40	49.40
60-90	6.40	0.06	0.51	0.879	30.45	273.5	9.8	232.6	2.90	3.20	32.60	48.30

Medium Black soil - Karjat												
0-30	7.0	0.14	1.29	2.22	40.86	258.3	18.4	270	3.00	3.56	31.60	25.80
30-60	7.2	0.11	0.68	1.17	34.40	259.4	17.4	282.5	3.51	3.10	25.62	21.40
60-90	6.9	0.13	0.46	0.79	37.59	247.8	15.6	260.4	2.40	2.91	25.10	21.50
Coastal saline soil - Panvel												
0-30	7.3	3.8	0.78	1.34	46.6	312.4	23.4	972.8	3.25	5.87	22.60	23.80
30-60	8.4	4.2	0.50	0.862	49.4	302.3	20.5	972.0	3.10	4.20	28.90	28.40
60-90	8.4	3.0	0.20	0.34	41.4	308.4	16.5	982.6	3.10	3.80	29.10	29.20

Table 11 :Nitrogen and potassium fractions in different types of soil profiles studied.

Soil depth (cm)	Nitrogen fractions (mg kg ⁻¹)			Potassium fractions (mg kg ⁻¹)			
	Ammcl-N	Nitrate-N	Total N (Amm.+ Nitrate)	Water sol-K	Exch. K	Ava. K	Non-Exch. K
Lateritic soil-Location Dapoli							
0-30	28.10	16.10	44.2	2.80	82.6	85.4	331.4
30-60	29.52	18.15	47.67	2.90	89.8	92.7	340.2
60-90	20.10	15.00	35.10	2.40	84.1	86.5	335.4
Medium Black soil-Location Karjat							
0-30	24.70	14.50	39.20	3.10	97.3	100.4	391.6
30-60	19.10	11.22	30.32	2.30	102.6	104.9	378.5
60-90	20.30	12.40	32.70	2.00	94.7	96.72	370.6
Coastal saline soil-Location Panvel							
0-30	31.00	19.40	50.40	128.6	233.2	361.8	432.4
30-60	26.10	17.28	43.38	120.0	241.6	361.6	428.8
60-90	28.80	18.65	47.45	120.0	254.5	365.5	402.6

Table 12: Phosphorous fractions in different types of soil profiles studied..

Soil depth (cm)	Phosphorous fractions(mg kg ⁻¹)						
	Saloid-P	Al-P	Fe-P	Ca-P	Occluded-P	Reductant soluble-P	Total inorganic P
Lateritic soil - Location Dapoli							
0-30	2.3	62.4	128.0	29.1	56.4	103.0	381.1
30-60	2.1	52.8	132.4	19.3	62.3	110.4	379.3
60-90	0.9	52.3	132.4	12.1	59.3	119.5	376.5
Medium Black soil - Location Karjat							
0-30	4.2	43.4	49.3	102.1	32.4	82.4	313.8
30-60	4.3	40.4	43.8	105.4	35.0	88.4	317.3
60-90	4.3	37.4	44.3	90.6	28.2	82.3	287.1
Coastal saline soil - Location Panvel							
0-30	8.9	52.6	59.6	113.8	35.2	84.4	354.5
30-60	9.4	56.2	52.3	108.5	32.3	89.2	347.9
60-90	6.2	53.4	52.0	108.5	38.4	90.6	349.0

Table 13: Leaching losses of nitrogen at different growth stages of rice crop as affected by various treatments (Year 2012)

Treatm ent	Nitrogen (mg pot ⁻¹)									Grand Total N loss	% N loss
	30 DAT			60 DAT			90DAT				
	NH ₄ ⁺ - N	NO ₃ ⁻ - N	Total N loss	NH ₄ ⁺ - N	NO ₃ ⁻ - N	Total N loss	NH ₄ ⁺ - N	NO ₃ ⁻ - N	Total N loss		
T ₁	38.4 8	19.5 2	58.00	30.9 6	15.1 2	46.08	27.7 9	12.1 7	39.95	144.03	21.6 7
T ₂	38.9 9	19.9 1	58.89	31.6 4	15.2 8	46.91	29.1 0	12.4 2	41.52	147.33	22.1 6
T ₃	39.2 2	20.1 4	59.35	31.7 3	15.3 7	47.10	29.3 1	12.5 3	41.84	148.29	22.3 1
T ₄	24.1 9	14.4 9	38.69	20.7 7	9.12	29.90	18.2 1	7.10	25.30	93.89	14.1 3
T ₅	24.9 3	14.9 3	39.86	21.1 5	9.35	30.51	18.2 5	7.27	25.52	95.88	14.4 3
T ₆	25.1 6	14.9 8	40.14	21.3 6	9.47	30.83	18.4 3	7.42	25.85	96.82	14.5 7
T ₇	9.49	7.95	17.44	9.00	5.71	14.71	5.39	3.33	8.72	40.88	6.15
T ₈	9.72	8.20	17.93	9.07	5.94	15.01	5.58	3.78	9.35	42.29	6.36
T ₉	9.84	8.23	18.06	9.16	6.04	15.20	5.67	3.96	9.63	42.89	6.45
SEm±	1.67	1.49		1.34	1.58		1.32	1.13			
CD@ 1%	4.82	4.30		3.86	4.55		3.81	3.25			

Table 15. Leaching losses of phosphorous at different growth stages of rice crop as affected by various treatments.

Treatment	2012 ($\mu\text{g pot}^{-1}$)				% P loss	2013 ($\mu\text{g pot}^{-1}$)				% P loss
	30 DAT	60 DAT	90 DAT	Total loss		30 DAT	60 DAT	90 DAT	Total loss	
T ₁	4064.0	1936.0	1056.0	7056.0	3.16	3440.0	1504.0	816.0	5760.0	2.58
T ₂	4074.7	2000.0	1120.0	7194.7	3.22	3504.0	1536.0	880.0	5920.0	2.65
T ₃	4144.0	2032.0	1136.0	7312.0	3.28	3520.0	1541.3	896.0	5957.3	2.67
T ₄	2928.0	1509.3	816.0	5253.3	2.35	2768.0	954.7	784.0	4506.7	2.02
T ₅	2960.0	1552.0	848.0	5360.0	2.40	2816.0	976.0	832.0	4624.0	2.07
T ₆	3008.0	1584.0	912.0	5504.0	2.47	2848.0	992.0	848.0	4688.0	2.10
T ₇	1664.0	1312.0	736.0	3712.0	1.66	1280.0	688.0	656.0	2624.0	1.18
T ₈	1712.0	1344.0	768.0	3824.0	1.71	1312.0	704.0	688.0	2704.0	1.21
T ₉	1744.0	1360.0	784.0	3888.0	1.74	1392.0	736.0	704.0	2832.0	1.27
SEm _±	0.67	0.26	0.24			0.28	0.26	0.34		
CD@ 1%	1.95	0.74	0.71			0.82	0.76	0.99		

Table 16: Leaching losses of potassium at different growth stages of rice crop as affected by various treatments (2012).

Treatment	K (mg pot^{-1}) 2012				% K loss
	30 DAT	60 DAT	90 DAT	Total loss	
T ₁	29.16	13.81	8.90	51.88	23.24
T ₂	29.40	14.07	9.16	52.63	23.58
T ₃	29.70	14.31	9.52	53.53	23.98
T ₄	18.44	13.35	7.90	39.70	17.79
T ₅	18.68	13.77	8.32	40.78	18.27
T ₆	19.04	14.01	8.50	41.56	18.62
T ₇	65.27	47.90	25.15	138.32	61.97
T ₈	65.75	48.08	25.57	139.40	62.46
T ₉	66.11	48.38	25.75	140.24	62.83
SEm _±	1.02	1.15	1.29		
CD@ 1%	2.93	3.30	3.72		

Table 17: Leaching losses of potassium at different growth stages of rice crop as affected by various treatments (2013).

Treatment	K (mg pot^{-1}) 2013	% K loss
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	30 DAT	60 DAT	90 DAT	Total loss	
T ₁	25.33	18.32	11.44	55.09	24.68
T ₂	25.63	18.50	11.68	55.81	25.00
T ₃	25.81	18.68	12.04	56.53	25.33
T ₄	15.81	12.81	8.86	37.49	16.79
T ₅	16.11	12.93	9.16	38.20	17.12
T ₆	16.29	13.17	9.40	38.86	17.41
T ₇	59.76	46.95	27.96	134.67	60.34
T ₈	60.66	47.43	28.08	136.17	61.01
T ₉	60.90	47.60	28.14	136.65	61.22
SEm±	1.04	1.12	0.90		
CD@ 1%	3.00	3.23	2.60		

Table 25. Effect of different treatments on nitrogen, phosphorous and potassium content in straw of rice.

Treatment	2012 (%)			2013 (%)		
	Total N	Total P	Total K	Total N	Total P	Total K
T ₁	0.73	0.182	1.817	0.75	0.173	1.703
T ₂	0.79	0.189	1.833	0.78	0.182	1.736
T ₃	0.81	0.194	1.857	0.79	0.189	1.743
T ₄	0.86	0.207	1.541	0.91	0.219	1.570
T ₅	0.91	0.220	1.546	0.96	0.228	1.572
T ₆	0.92	0.243	1.549	0.99	0.231	1.576
T ₇	0.61	0.150	1.727	0.64	0.148	1.690
T ₈	0.68	0.169	1.742	0.68	0.159	1.699
T ₉	0.70	0.174	1.746	0.69	0.163	1.709
SEm±	0.035	0.017	0.020	0.026	0.010	0.023
CD@ 1%	0.074	0.037	0.032	0.056	0.021	0.071

Table 26: Effect of different treatments on uptake of nitrogen by grain and straw of rice crop

Treatment	2012 (mg kg ⁻¹)			2013 (mg kg ⁻¹)		
	Grain N uptake	Straw N uptake	Total N uptake	Grain N uptake	Straw N uptake	Total N uptake

T ₁	161.7	111.8	273.6	160.6	114.4	275.1
T ₂	181.5	125.7	307.2	185.9	136.7	322.7
T ₃	189.2	149.7	338.9	195.1	145.1	340.2
T ₄	260.1	184.8	445.0	252.6	206.6	459.3
T ₅	277.7	224.4	502.1	264.2	243.6	507.8
T ₆	290.4	231.0	521.5	271.8	253.2	525.1
T ₇	102.6	75.8	178.4	104.9	81.9	186.8
T ₈	110.1	89.2	199.3	113.4	90.6	204.0
T ₉	115.0	91.6	206.7	119.6	93.9	213.6
SEm _±	9.31	8.79	10.81	5.59	6.22	8.53
CD@ 1%	26.80	25.32	31.13	16.09	17.93	24.56

Table 28: Effect of different treatments on uptake of p by grain and straw of rice crop at harvest stage

Treatment	2012 (mg kg ⁻¹)			2013 (mg kg ⁻¹)		
	Grain uptake	Straw uptake	Total uptake	Grain uptake	Straw uptake	Total uptake
T ₁	18.30	28.00	46.36	18.58	26.34	44.93
T ₂	21.36	33.98	55.34	22.82	31.42	54.24
T ₃	22.70	35.34	58.05	24.31	34.02	58.33
T ₄	28.62	43.69	72.31	32.79	49.87	82.67
T ₅	30.84	54.01	84.86	34.30	56.87	91.17
T ₆	31.78	61.09	92.87	35.94	59.23	95.18
T ₇	10.72	18.84	29.56	10.85	19.02	29.87
T ₈	12.88	22.05	34.93	11.81	21.34	33.16
T ₉	13.41	22.89	36.31	12.21	22.17	34.38
SEm _±	1.96	3.36	3.99	1.29	2.15	2.73
CD@ 1%	5.64	9.67	11.51	3.74	6.20	7.85

Table 28: Effect of different treatments on uptake of potassium by grain and straw of rice crop at harvest stage

Treatment	2012 mg kg ⁻¹			2013 mg kg ⁻¹		
	Grain K uptake	Straw K uptake	Total K uptake	Grain K uptake	Straw K uptake	Total K uptake
T ₁	37.0	278.64	315.7	36.98	262.9	299.9
T ₂	40.95	328.04	368.9	42.24	293.5	335.7
T ₃	43.07	337.23	380.3	43.59	314.9	358.5
T ₄	45.62	326.30	371.9	41.28	357.8	399.1
T ₅	47.70	380.26	427.9	42.84	400.2	443.0
T ₆	49.59	388.12	437.7	44.46	404.0	448.4
T ₇	28.29	215.98	244.2	27.81	216.3	244.1
T ₈	29.97	227.93	257.9	29.84	227.6	257.5
T ₉	30.83	228.80	259.6	31.21	231.5	262.7
SEm _±	2.84	11.49	11.97	2.25	9.90	10.1
CD@ 1%	8.18	33.09	34.48	6.48	28.52	29.2

stages of rice

Treatment	kg ha ⁻¹ (2012)				kg ha ⁻¹ (2013)			
	30 DAT	60 DAT	90 DAT	AH	30 DAT	60 DAT	90DAT	AH
T ₁	333.4	354.4	296.9	301.1	326.8	342.1	302.0	299.6
T ₂	353.6	376.8	306.5	307.2	344.9	362.1	309.1	305.1
T ₃	358.5	383.4	310.1	309.6	351.8	371.2	313	307.7
T ₄	308.6	340.9	298.5	284.8	310.7	334.2	306.2	279.4
T ₅	336.1	370.1	316.7	292.8	332.0	363.3	324.1	288.1
T ₆	345.6	380.2	319.9	295.4	341.0	376.2	330.1	292.1
T ₇	344.1	356.1	334.7	338.1	338.2	350.1	318.1	342.2
T ₈	359.4	372.2	340.2	341.5	352.0	361.0	324.0	346.0
T ₉	363.0	375.1	341.9	342.4	357.1	366.1	327.2	348.3
SEm _±	4.75	2.79	2.75	2.23	4.21	2.35	2.43	2.32
CD@ 1%	13.6	11.3	11.1	9.11	12.12	9.56	9.90	9.47

Table 31: Effect of different treatment on available phosphorous at different growth stages of rice.

Treatment	Ava. P ₂ O ₅ kg ha ⁻¹ (2012)				Ava. P ₂ O ₅ kg ha ⁻¹ (2013)			
	30 DAT	60 DAT	90 DAT	AH	30 DAT	60 DAT	90 DAT	AH
T ₁	12.9	15.60	13.4	11.8	13.1	16.0	13.8	12.0
T ₂	14.7	17.80	14.6	12.5	14.8	18.9	15.0	12.8
T ₃	15.53	18.50	15.0	12.8	15.4	19.7	15.4	13.2
T ₄	22.93	26.50	24.6	23.4	20.2	24.1	23.2	21.8
T ₅	25.2	29.90	26.5	24.6	23.3	27.1	24.1	23
T ₆	25.8	30.70	27.0	25.5	24.1	28.7	24.7	23.9
T ₇	28.9	32.00	30.8	27.7	27.5	30.5	29.2	26.2
T ₈	30.1	32.90	31.6	28	28.9	31.2	29.6	26.5
T ₉	30.5	33.10	31.9	28.2	29.4	31.6	29.8	26.76
SEm _±	0.62	0.61	0.49	0.41	0.50	0.53	0.54	0.42
CD@ 1%	2.55	2.48	2.02	1.70	2.06	2.15	2.19	1.71

Table 14: Leaching losses of nitrogen at different growth stages of rice crop as affected by various treatments (Year 2013)

Treatm ent	Nitrogen (mg pot ⁻¹)									Grand Total N loss	% N loss
	30 DAT			60 DAT			90DAT				
	NH ₄ ⁺ -N	NO ⁻ ₃ -N	Total N loss	NH ₄ ⁺ -N	NO ⁻ ₃ -N	Total N loss	NH ₄ ⁺ -N	NO ⁻ ₃ -N	Total N loss		
T ₁	36.2 4	18.7 1	54.95	26.9 6	14.2 6	41.22	25.6 5	11.1 3	36.77	132.94	20. 00
T ₂	37.6 0	19.2 6	56.86	28.4 8	14.4 9	42.97	25.8 5	11.4 4	37.29	137.12	20. 63
T ₃	38.3 9	19.3 3	57.72	28.6 2	14.6 3	43.25	25.9 4	11.4 7	37.42	138.39	20. 82
T ₄	31.5 7	10.7 6	42.33	24.1 2	7.63	31.75	18.4 8	7.19	25.67	99.75	15. 01
T ₅	31.8 4	11.8 4	43.69	24.5 2	8.27	32.79	18.8 0	7.44	26.24	102.72	15. 45
T ₆	31.9 4	12.4 2	44.35	24.7 0	8.47	33.17	18.9 6	7.67	26.64	104.16	15. 67
T ₇	11.8 4	7.44	19.29	7.93	5.69	13.62	7.05	3.50	10.55	43.46	6.5 4
T ₈	12.0 5	7.81	19.86	8.16	5.71	13.87	7.19	3.48	10.67	44.40	6.6 8
T ₉	12.3 7	7.88	20.25	8.27	5.88	14.15	7.33	3.71	11.04	45.44	6.8 4
SEm±	1.56	1.43		1.75	1.28		1.60	1.08			
CD@ 1%	4.49	4.12		5.05	3.69		4.62	3.13			

